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1990 Report to the Congress on the

Strategic Defense Initiative

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May 1990

Prepared by the Strategic Defense Initiative Organization

THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

7 JUN 1990

The Honorable Sam Nunn
Chairman
Committee on Armed Services
United States Senate

The Honorable John Warner
Ranking Republican
Committee on Armed Services
United States Senate

The Honorable Robert C. Byrd
Chairman
Committee on Appropriations
United States Senate

The Honorable Mark O. Hatfield
Ranking Republican
Committee on Appropriations
United States Senate

The Honorable Jamie L. Whitten
Chairman
Committee on Appropriations
House of Representatives

The Honorable Silvio O. Conte
Ranking Republican
Committee on Appropriations
House of Representatives

The Honorable Les Aspin
Chairman
Committee on Armed Services
House of Representatives

The Honorable William L. Dickinson
Ranking Republican
Committee on Armed Services
House of Representatives

This forwards the 1990 Report to Congress on the Strategic Defense Initiative, as required by Section 224 of the FY1990/1991 Department of Defense Authorization Act.

The report recounts the progress the program has made over the last several years and describes our plans for the future. If adequately supported by Congress, I am confident that the program we propose will support an informed decision by the President within the next three years on the deployment of strategic defenses. One of the biggest breakthroughs occurred recently--and you are probably familiar with it: the introduction of the Brilliant Pebbles concept into the space-based portion of the defense architecture. The Defense Science Board and the JASONs independent technical group each reviewed the Brilliant Pebbles concept and recommended we continue to pursue it. While they found no technical "showstoppers," they did recommend a number of technical improvements which we are incorporating. We will begin testing Brilliant Pebbles this summer and have structured the program to allow early demonstration of its feasibility.

Preliminary cost estimates and effectiveness analyses indicate that deployment of Brilliant Pebbles as the space-based layer of a Phase One Strategic Defense System could allow savings of $14 billion from previous estimates, reducing the

cost of an initial system from $69 billion to approximately $55 billion. Brilliant Pebbles would allow this savings while maintaining the same effectiveness as previous proposals. Brilliant Pebbles provides the additional military benefits of increased survivability through proliferation and enhanced availability through autonomy. We will keep you informed of progress on this key element of the SDI program, and our ongoing efforts to further reduce overall costs.

In addition to the maturation of the Brilliant Pebbles concept, we are beginning to see the fruits of our investment in developing a wide range of strategic defense technologies. In 1989, we launched the Beam Experiment Aboard a Rocket (BEAR), which demonstrated propagation of a particle beam in space. Also in 1989, we witnessed the first firing of the Alpha chemical laser. In 1990, we plan to achieve even more significant testing milestones. In January, we launched the first High Endo-Atmospheric Defense Interceptor (HEDI) test and demonstrated the ability to cool the interceptor's forebody and sensor window. The Brilliant Pebbles tests scheduled this summer will demonstrate the capability to acquire and track an object. Also in 1990, we plan to demonstrate that we can detect boosters against a variety of earth backgrounds.

We are demonstrating defensive technologies that we believe offer the potential for moving toward a more stable relationship with the Soviet Union while reducing offensive forces. In fact, the U.S. has proposed a draft treaty in the Defense and Space Talks (DST) in Geneva that would facilitate a cooperative transition toward a more stable strategic regime that includes both offensive and defensive forces. The Soviets have thus far refused to engage with us on substantive issues in the DST. Recent debate within the Soviet Union--with some supporting the stabilizing nature of strategic defenses--is cause for hope, however, that we can achieve the goal of improving stability by a cooperative transition to greater reliance on strategic defenses.

Defenses would complement U.S. arms control objectives and could become even more important in a regime with reduced offensive forces. Defenses would reduce the utility of missiles with multiple independently targetable reentry vehicles (MIRVs) by threatening them in the boost and post-boost phases. Thus, defenses directly support de-MIRVing, a key objective of U.S. arms reduction policy. Additionally, even though the utility of each missile would increase under a START treaty regime, defenses would reduce the incentive to cheat by reducing any military advantage to be gained by cheating.

In sum, our efforts to demonstrate defensive technologies, to modernize our offensive forces and to work toward beneficial arms control agreements are fully integrated and mutually

reinforcing. In the area of strategic defense, our accomplishments are reshaping the debate over defenses from one based on broad statements that defense won't work, to consideration of the many useful military missions defenses can perform. I believe that in the 1990s strategic defense makes much more sense than ever before, and I urge your support for the President's funding request for Fiscal Year 1991 for the Strategic Defense Initiative program.

Dick Cheney

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SDI Program in Perspective

Chapter 1
SDI Program in Perspective

This chapter describes the policy associated with the SDI Program, including the rationale for defenses, the implications of the evolving international environment for this policy rationale, recent Presidential decisions on SDI, and recent developments in the definition of defense architectures. Section 1.2.1 describes U.S. efforts in the Defense and Space Talks to pave the way for a cooperative transition to a more stable strategic relationship with the Soviet Union based on a balanced mix of offensive and defensive weapons.

1.1 SDI in Perspective

The nature of the threat we face has changed and will continue to change over the next decade. In the 1950s and into the 1960s, the United States relied on its virtual monopoly and later its large advantage in nuclear weapons and delivery means and used the threat of massive retaliation to deter a Soviet attack against the United States and its allies. In response to growth in the Soviet nuclear arsenal in the 1960s, the United States gradually moved from a policy of massive retaliation to deter Soviet attack to one of flexible response.

At the same time the Soviet Union was expanding its offensive arsenal, it was deploying air defenses to protect itself against U.S. strategic bombers. The United States also deployed significant air defenses, and both we and the Soviets began development and deployment of defenses against ballistic missiles. The United States and the Soviet Union agreed in 1972 (in the SALT I Interim Agreement and Antiballistic Missile [ABM] Treaty) to limit growth of offensive arsenals, to seek future reductions in offensive forces, and to place significant limits on ABM systems. After the ABM Treaty was signed, the United States made little effort to defend against Soviet strategic nuclear attack, either from ballistic missiles or bombers. Our defensive efforts were basically confined to passive measures, such as hardening of intercontinental ballistic missile (ICBM) silos and critical command and control facilities. We in the United States accepted the premise on which the ABM Treaty was based—that deployment of defenses available in 1972 would spur growth of offensive forces. This led to U.S. acceptance of mutual vulnerability.

We believe, however, that the Soviets have not accepted the condition of mutual vulnerability that was a desired result of the ABM Treaty. The Soviet Union has continued to expand its air defenses, deployed the world's only operational ballistic missile defense system around Moscow, and developed extensive passive defenses, including reinforced silos to protect its missiles and a civil defense program to protect its leadership. Moreover, the Soviets have long maintained an intensive program to develop advanced defenses against ballistic missiles. The Soviets' refusal to accept mutual vulnerability is further evidenced by the continued growth in the Soviet offensive arsenal and their pursuit of the capability to exercise a nuclear first strike against U.S. military forces. The Soviets continue to invest as much on strategic defenses, including air defense, as they do on strategic offensive forces.

The military challenge presented to us by the Soviets, and our potential to exploit emerging technologies that held the promise of providing effective defenses, caused the United States, in the early 1980s, to begin to rethink its decision to forego defenses

against ballistic missiles. Soviet actions pursuant to the ABM Treaty have shown that the hope that the abandonment of significant ballistic missile defenses would eliminate incentives for the Soviets to proliferate offensive forces and encourage offensive force reductions was ill-founded. Second, although technology available in 1972 did not permit truly effective defenses—only ground-based, limited-area defenses using nuclear-armed interceptors which might be easily countered—1980s technology offered the promise of effective defenses that could render ballistic missiles obsolete.

Consequently, in the 1980s the United States responded to Soviet deployments of offensive counterforce weapons and improvements in defensive capabilities by increasing the accuracy, penetration capability, and survivability of our deployed strategic offensive forces and the survivability of critical command, control, and communications assets. We also began to reexamine the potential role of active defenses. Building on several ongoing research and development programs, we established the SDI Program to conduct a broadly based research and development effort to determine the feasibility of effective ballistic missile defenses.

In part, our desire to pursue SDI was based on a survey of the technological capability of the United States. This led to the conclusion that the state of the art in defensive technologies had progressed to the point where it was reasonable to investigate whether these new technologies could permit us to turn to defense to enhance deterrence and provide a more secure and stable long-term basis for deterrence.

The goal of Phase I strategic defenses remains the same—that is, to enhance deterrence of Soviet attack by increasing uncertainty as to the potential to achieve the attack's objectives. If deterrence fails, Phase I defenses could provide some protection of military and civilian targets and, hence, deny certain Soviet military objectives. In addition, the defenses could be very effective in protecting the United States from limited or accidental ballistic missile launches. In this case, Phase I defenses could provide meaningful population protection.

The United States is considering, in its evaluation of options generated by SDI research, the degree to which certain types of defensive systems discourage an adversary from attempting to overwhelm them with additional offensive capability. We seek defensive options—as with other military systems—that can maintain capability more easily than countermeasures could be taken to try to defeat them.

1.2 SDI and the Evolving International Security Environment

The international security environment that the United States faces is changing. As relations between the United States and the Soviet Union improve, some have raised questions as to the need for expenditures on additional U.S. strategic forces, including the SDI Program. We believe that the SDI Program, as well as our strategic offensive force modernization programs, remains critical for ensuring our future security. Furthermore, if the Soviets are sincere about pursuing a defensive military doctrine (and they have taken steps in that direction in the conventional area), they should welcome greater mutual reliance on strategic defenses that threaten no one. Last, the rise of regional powers, some possessing ballistic missile technology and nuclear, chemical, and biological warheads, poses a substantial threat to the United States and its friends and interests worldwide.

Notwithstanding the improvements in United States-Soviet Union relations and announced Soviet intentions to reduce emphasis on military spending, particularly that focused on conventional capability, Soviet strategic modernization continues today at an

impressive pace. Moscow is in the process of modernizing a strategic force which has already been upgraded significantly over the past 10 years. These new Soviet forces—including the SS-18 Mod 5, mobile SS-24, and SS-25 ICBMs, and Typhoon- and Delta IV-class ballistic missile submarines—will allow the Soviets to pose an increasingly diverse and flexible threat to the United States and our allies. And, as previously mentioned, Soviet strategic defense modernization continues at a robust pace.

1.2.1 Defense and Space Talks

The United States wishes to pave the way for a cooperative transition to a world in which effective defenses against ballistic missile attack play an increasing role in ensuring deterrence. The United States is pursuing this objective with the Soviet Union in the Defense and Space Talks.

The U.S. position in the Defense and Space Talks is consistent with and supportive of the objectives of the SDI Program. We seek an agreement that would help provide a stable, predictable basis for developing and testing advanced defenses against ballistic missiles and for deploying such defenses when they are ready. We have rejected Soviet proposals to constrain the SDI Program and Soviet demands that the United States waive or forfeit its existing rights under the ABM Treaty. We must not close off promising avenues of technological research before they yield answers to the fundamental question of whether effective strategic ballistic missile defenses are feasible.

1.2.2 SDI and Strategic Arms Reduction Talks

If negotiations between the United States and the Soviet Union continue on their current course, we expect a Strategic Arms Reduction Talks (START) agreement to enter into force in the near future. U.S. strategic defenses would be a natural complement to the offensive reductions of a START Treaty. First, defenses would offer insurance against possible Soviet cheating under a START Treaty regime. This insurance would be particularly important because the reductions resulting from a START Treaty would increase the marginal importance of each offensive weapon and thus the military significance of cheating. Protection against possible cheating would be important given the uncertainties associated with verification of mobile ICBM limits. Strategic defenses are an effective means of addressing the threat posed by Soviet mobile missiles. In addition, because space-based strategic defenses can destroy ballistic missiles with multiple independently targetable reentry vehicles (MIRVs) in the boost and post-boost phases, they would provide an incentive to "de-MIRV" consistent with U.S. arms control strategy.

1.2.3 Ballistic Missile Proliferation

Over the next 10 to 15 years, many additional nations will obtain ballistic missile capabilities sufficient to threaten U.S. interests worldwide, our friends and allies, and ultimately the United States itself. The Director of the Central Intelligence Agency has reported that at least 15 developing countries will be producing their own ballistic missiles by the year 2000. These missiles may be armed with nuclear, chemical, or biological weapons.

Because of the nature of some of these third world threats, deterrence based on the prospect of offensive retaliation may not be credible or effective, and defenses may be necessary to address them. Furthermore, should a variety of additional nations obtain ballistic missile technology, and the U.S. forces remain unprotected against

ballistic missile attack, it would seriously undermine our ability to carry out certain regional policies.

In addition, given the nature of the proliferation threat, there is likely to be an increased risk of accidental or unauthorized launches. Loss of positive control over ballistic missile forces is more likely to occur in the third world because of lack of experience, the absence of adequate physical and organizational safeguards, and the danger of political instability. Our ability to defeat these threats could deter these nations from obtaining such capability in the first place and would provide more flexibility in responding to their use, should deterrence fail.

By undermining the political and military utility of ballistic missiles, defenses would help to dampen the incentives for their proliferation and complement our nonproliferation policies. In the absence of such defenses, the United States could confront the future possibility that the combination of ballistic missiles and weapons of mass destruction could be used against its cities, forces, or allies with relative impunity by emerging powers.

1.2.4 Soviet Uncertainties

The Soviet Union is undergoing a dramatic process of political change. As we respond to these positive developments, however, we have a responsibility to recognize and address areas that remain unchanged. The current situation is marked by considerable uncertainty, and the Soviet Union remains a nuclear superpower. And while we have indications of reduced Soviet investment in conventional forces, their strategic modernization efforts continue. In short, the opportunities are great, but so are the uncertainties and risks.

These uncertainties and potential dangers for the United States and its allies underscore the need to maintain a robust SDI Program as a precaution against the possibility of instability in the Soviet Union.

1.3 Presidential Decisions

Upon entering office, President Bush called for a comprehensive review of our national security strategy and objectives. In doing so, he pressed the Executive branch to "challenge assumptions" concerning previous national security policies and programs, including SDI.

Based on that review, the President has determined the following:

- The goals of the SDI remain sound.
- Pursuit of the SDI Program provides a hedge against any Soviet decision to expand rapidly its ABM capability beyond that allowed by the ABM Treaty.
- The SDI Program will be conducted in a way that permits the President to make, within the next 3 years, an informed decision on deployment of strategic defenses.
- We will continue to pursue options for layered defenses, composed of both space- and ground-based elements, which offer the promise of meeting the stated JCS requirements for Phase I defenses.

- Particular emphasis should be given to determining the feasibility of promising concepts for effective boost-phase defenses, for example, "Brilliant Pebbles," on an expedited basis. Investigarion of particularly promising approaches should be limited by the pace of technical progress rather than by funding. The SDI Program should be configured to permit deployment of layered defenses on a schedule as close as possible to that envisioned in the Five-Year Defense Program submitted to the Congress in January 1989.
- The SDI Program will continue to be conducted in full compliance with the ABM Treaty.

With his decision to continue pursuing options for layered defenses, the President recognized the leverage space-based defenses would provide by threatening enemy boosters and post-boost vehicles. He also realized that deterrence could be significantly enhanced by a space-based defensive system's ability to create large uncertainty in the results of a structured attack, thereby reducing the likelihood of a first-strike attack.

The President's decisions affirm SDI's goal—to conduct a vigorous research and technology program that could provide the basis for an informed decision regarding the feasibility of eliminating the threat posed by ballistic missiles of all ranges and to increase the contribution of antiballistic missile defense systems to United States and allied security. Deployment of these effective ballistic missile defenses would permit a major shift in our strategy from emphasizing the threat of retaliation to emphasizing direct denial of Soviet war aims, and would provide a true damage-limiting capability for the United States should deterrence fail.

1.4 Recent Developments

The Defense Science Board (DSB) and the JASONs have recently reviewed the Brilliant Pebbles concept. The groups found the concept innovative and capable, with no fundamental flaws, and deserving of continued support. Both made useful suggestions of technical improvements, which have been incorporated into the program. The Strategic Defense Initiative Organization (SDIO) has performed initial cost estimates of the Brilliant Pebbles concept and believes that it could reduce the cost of a Phase I system by at least 20 percent. SDIO believes that these estimates are conservative, especially in light of the opportunities for innovation in manufacturing technology for producing large numbers of identical Pebbles.

The President directed an independent review of the SDI Program. This review is nearing completion. The preliminary results of the study are consistent with those of the DSB and the JASONs—Brilliant Pebbles provides the promise of an innovative approach to space-based defenses. Furthermore, the study recommended ways to export the innovative architectural and technical approach from Brilliant Pebbles to other parts of the Program. The detailed results of the review will be available in the near future.

Chapter 2

Strategic Defense System Concept

Chapter 2
Strategic Defense System Concept

This chapter summarizes key strategic defense concepts and analyses, expected threats, system mission requirements, and initial and follow-on architectures.

2.1 Strategic Defense Concepts and Analysis

In 1983 the President challenged the U.S. scientific community to investigate whether new technologies could be used to counter nuclear ballistic missiles. Shortly after this challenge, the President directed that an intensive analysis be conducted to identify the most promising technologies. That analysis was known as the Defensive Technologies Study, or Fletcher Study. Among other things, it concluded that the most effective defensive systems would have multiple layers. In particular, the study indicated that, unlike earlier defenses, both kinetic and directed energy approaches now exist for intercepting a ballistic missile during the boost portion of its flight.

The Fletcher Study concept of multilayered defense, which begins upon launch of a ballistic missile, remains today the conceptual cornerstone of the Strategic Defense System (SDS). Specifically, the SDS consists of layers referred to as boost/post-boost, midcourse, and terminal. These layers correspond, respectively, to (1) the first few seconds of a missile's flight after launch through the time its reentry vehicles (RVs) and decoys are deployed, (2) the relatively long period of time the RVs and decoys coast along their ballistic trajectories in space, and (3) the final minute or so when the RVs *reenter the atmosphere near their targets.*

The Fletcher Study also recognized that the phenomenology and required technologies for defense in each layer are quite different. However, the basic functions remain the same: (1) surveillance, acquisition, and tracking (that is, sensing); (2) intercept and destruction of threatening objects; and (3) battle management, command, control, and communications (BM/C^3). Thus, as new technologies continue to emerge, they can provide better approaches for accomplishing the essential functions in the defensive layers without changing the overall system concept. These technologies involve both space- and ground-based defensive interceptors and their associated sensors and command and control capabilities.

The region of highest defense payoff is the boost/post-boost layer because intercepts in that region destroy more of the threat per kill than in the other layers. This leverage results from the fact that each booster and its post-boost vehicle normally carry multiple RVs. An example of the use of emerging technologies to perform the intercept function in the boost/post-boost layer is Brilliant Pebbles, an autonomous space-based kinetic energy interceptor that has replaced earlier approaches. Nevertheless, development of an earlier approach known as SBI (referring to a specific type of space-based interceptor technology) has been continued at a reduced pace to serve as a backup concept to Brilliant Pebbles. The boost/post-boost layer is a major research area, driving toward the use of space-based elements for defense.

For the midcourse layer, a second major research area is the technical challenge to develop sensors that can discriminate RVs from the large number of their accompanying decoys or from debris. A third major area of research is defense in the terminal layer against remaining warheads as they reenter the atmosphere, and a fourth is the assurance of effective BM/C^3 with human control of the system.

2.2 Threat

The SDS must be able to counter a Soviet offensive threat and survive defense suppression threats. The dynamic nature of the threat also requires a system design and an architecture that are responsive.

Threat changes may result from Soviet technological advances such as offensive threat enhancements that include a proliferation of RVs, multiple post-boost vehicles per booster, fast-burn boosters, maneuverable RVs, and multifaceted penetration aids. Likewise, in addition to the already existing co-orbital antisatellite (ASAT) systems, we anticipate facing evolutionary enhancements to the defense suppression threat that include improved direct-ascent ASATs and directed energy and kinetic energy weapons. These advancements in technology and quantity will be coupled with new strategic concepts and challenging tactics. Threat changes can also involve factors such as arms control reductions.

The SDI Program conducts continuing analyses to understand how the evolution of the threat impacts SDS performance. This effort, coupled with the involvement of the defense and intelligence communities through the Strategic Defense Initiative Organization (SDIO) Threat Working Group, helps SDIO define more clearly the threat and incorporate appropriate enhancements into the SDS architecture.

2.3 Mission Requirements

The Phase I SDS has been designed to serve as the first in a series of deployments leading to a more balanced deterrent posture based on offensive and defensive forces. With this understanding, the Joint Chiefs of Staff (JCS) issued in 1987 a formal statement of mission objectives and required system characteristics. The JCS requirements provided the military's views on the minimum defensive capability that would add meaningfully to deterrence of a Soviet first strike. The requirements for system characteristics were intended to provide minimum technical performance levels with which to measure Phase I system effectiveness.

Subsequent to this, the Chairman of the JCS, in implementing the Goldwater-Nichols Department of Defense Reorganization Act of 1986, requested that the Unified and Specified Commands identify operational requirements for force structures. As a result, in October 1989 (subsequently updated in March 1990) the Commander-in-Chief of Space Command (USCINCSPACE) issued a formal set of operational requirements based on JCS Phase I requirements and the USCINCSPACE long-term ballistic missile defense (BMD) strategy.

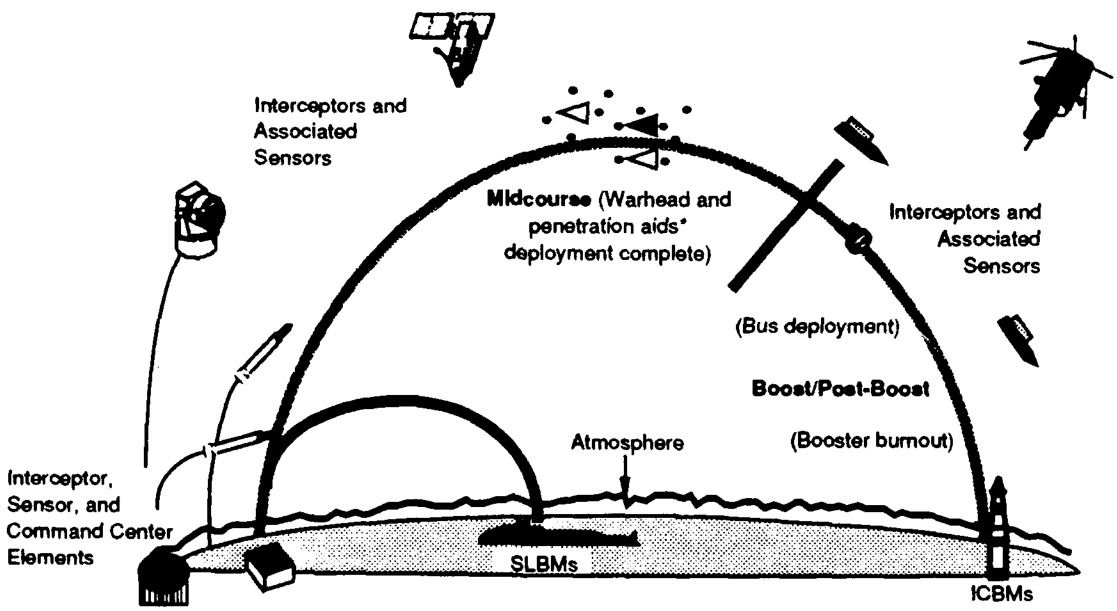
In support of this strategy, USCINCSPACE developed mission objectives, mission requirements, and a detailed and quantified set of operational requirements *(USCINCSPACE Operational Requirements for Phase I Strategic Ballistic Missile Defense)*. These requirements are currently undergoing the Joint Requirements Oversight Committee validation process.

The detailed operational requirements support the mission requirements. Using this approach, USCINCSPACE has converted the original JCS broad mission guidance into a flexible operational concept for strategic defenses that will provide a timely and militarily useful response to National Command Authority guidance across the full spectrum of conflict from peace to war.

2.4 Initial Architecture

The initial architecture for an SDS must meet the quantitative and qualitative requirements established by the JCS, must not be overly vulnerable to threat excursions, and must be capable of growth to higher levels of effectiveness. The architecture chosen for the first phase of the SDS is a two-layer system that operates in the boost/post-boost layer as well as the midcourse layer. The system employs both space-based and ground-based kinetic energy interceptors and their associated sensors and command and control capabilities (see Figure 2-1). Figure 2-2 presents the primary functions for the system and lists candidate elements to perform these functions in the Phase I architecture. The exact allocation of functions will be determined by the system design and the choice of competing concepts for the elements. For example, due to technology development, individual interceptors such as Brilliant Pebbles can be given more capability, thereby reducing requirements for the sensors. Details of the elements are provided in Chapter 5.

Figure 2-1
Phase I SDS Architecture



* Penetration aids are devices, such as decoys, that are used to try to confuse defenses.

To support this architecture, there must be an investment in interceptor development and for the creation of an infrastructure of sensors and battle management capability. Once this investment is made, the mix of interceptor types may be adjusted to meet the JCS requirements against the threat. Figure 2-3 displays how different Soviet countermeasures could affect the relative balance in the number of ground-based and space-based interceptors.

As Figure 2-3 shows, the significant countermeasures to space-based kinetic energy interceptors are shorter timelines imposed by the target (booster or post-boost vehicle [PBV]) and ASAT weapons. Likewise, if the Phase I system's ability to discriminate RVs from decoys is reduced by better penetration aids or sensor degradation, then midcourse interceptors become less effective. The presence of a two-

Figure 2-2
Initial System Functions and Elements

PRIMARY FUNCTIONS	ELEMENTS
• Detect missiles launched • Acquire and track boosters	Boost Surveillance and Tracking System (BSTS)
• Acquire and track post-boost vehicles and reentry clusters, ASATs, and satellites	Space-Based Surveillance and Tracking System (SSTS)
• Acquire and track reentry clusters • Resolve closely spaced objects • Track RVs and penetration aids • Discriminate RVs from penetration aids	Ground-Based Surveillance and Tracking System (GSTS)
• Perform acquisition and tracking • Discriminate RVs from penetration aids	Ground-Based Radar (GBR)[1]
• Destroy RVs in late midcourse	Ground-Based (Exoatmospheric) Interceptor (GBI)
• Acquire and track boosters, post-boost vehicles, and ASATs • Destroy boosters, post-boost vehicles, and ASATs	Space-Based Kinetic Energy Interceptor (Brilliant Pebbles)[2]
• Provide human decisionmaking • Provide for communications with decision makers and forces • Execute battle plan • Assess kill • Provide guidance for system operation and integration functions	Command Center (CC)

1 All Defense Acquisition Board requirements have been met for a GBR Milestone I decision. Final Under Secretary of Defense (Acquisition) approval is pending.

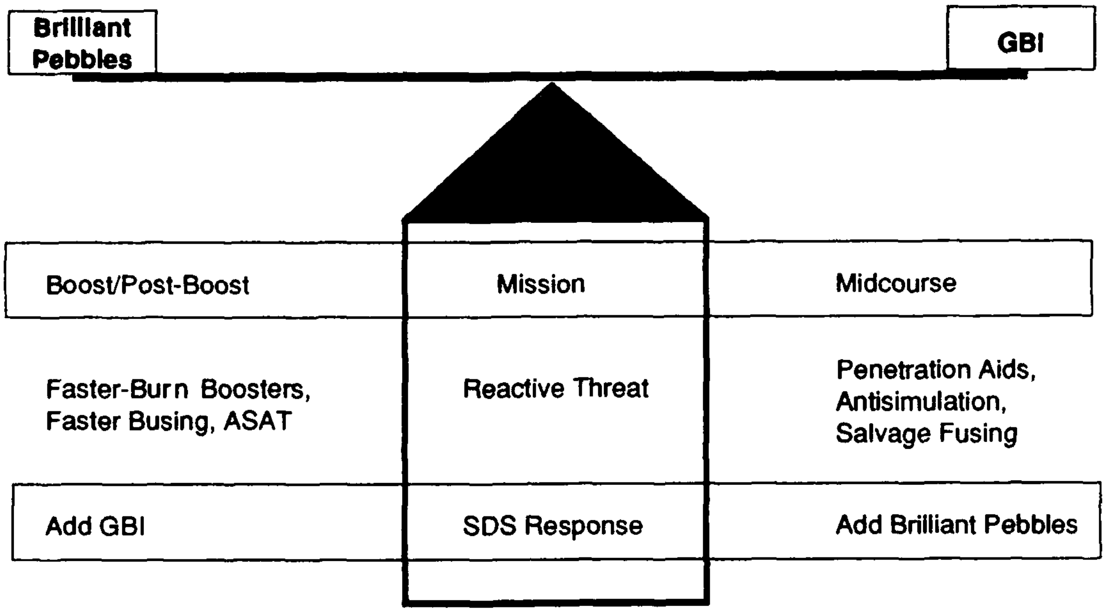
2 SBI (Space-Based Interceptor) is a backup concept to Brilliant Pebbles for the function of destroying boosters, post-boost vehicles, and ASATs.

layer SDS will present the Soviet planner with a dilemma because achieving shorter timelines and better penetration aids are contradictory goals and can be very expensive. As the threat develops, system performance can be restored by increasing the number of either or both types of interceptors, or by adding follow-on elements to the architecture.

2.5 Follow-on Architectures

The selection of an evolutionary path to an increasingly capable SDS will depend heavily on how the threat may change in response to the deployment of Phase I, the mission effectiveness desired, and the technologies available and their costs. The SDI Program is examining a variety of concepts for advanced weapon and sensor elements and is developing the required technologies to support them. SDIO has been analyzing possible follow-on architectures for 2 years. Primary functions and examples of the kinetic and directed energy elements under study to perform these functions are provided in Figure 2-4. The associated development projects are discussed in Chapter 6.

Figure 2-3
Phase I Interceptor Resiliency



The current SDI weapons development programs, made up of kinetic energy devices, high-energy lasers, and high-energy particle beams, present an adversary with the daunting prospect of having to simultaneously survive three different killing phenomenologies. A response to any one of these elements makes the adversary vulnerable to another. The potential for deployment of these mutually supporting capabilities offered by this "development triad" makes the SDI Program highly resilient to the employment of cheap and easy countermeasures.

Specific operational requirements must be analyzed further before details of a follow-on architecture can be defined. Preliminary observations, however, suggest that the architecture should be able to do the following:

- Build on the Phase I infrastructure and increase the concentration of and improve kinetic energy interceptors, possibly adding a terminal defense layer

- Add directed energy weapons, i.e., lasers (space-based or ground-based) and/or neutral particle beams, either sequentially or concurrently, to provide multiple capabilities to destroy boosters and PBVs and discriminate RVs from decoys in the midcourse layer.

Figure 2-4
Follow-on Functions and Candidate Elements

PRIMARY FUNCTIONS	CANDIDATE ELEMENTS
• Destroy RVs after reentry (terminal defense)	High Endoatmospheric Defense Interceptor (HEDI)
• Destroy boosters, PBVs, and ASATs • Perform interactive discrimination	Space-Based Laser (SBL) and Ground-Based Laser (GBL)
• Interactive discrimination • Destroy boosters, PBVs, RVs, and ASATs	Space-Based Neutral Particle Beam (NPB)
• Destroy RVs in late terminal layer	Ground-Based Hypervelocity Gun (HVG)
• Destroy boosters, PBVs, and ASATs • Destroy RVs in early midcourse	Space-Based HVG

Another promising element under investigation is the hypervelocity gun for both space-based and terminal roles. Also under study is the potential to combine the inherent sensor capabilities of different weapon platforms. This combination could yield a more complete picture of the battle, thereby enhancing the effectiveness of the architecture and possibly reducing certain technical requirements on the weapons.

2.6 Summary

As operational requirements become more clearly defined and technology development continues to make significant strides, the SDI Program will concentrate more on providing the basis for an informed decision on the development and acquisition of a multilayered strategic defense against ballistic missiles. The system concept and the basic defensive functions remain unchanged. The use of Brilliant Pebbles as part of the Phase I architecture is indicative of efforts the SDI Program is undertaking to advance technology and develop the most effective strategic defense system possible at an affordable cost.

Chapter 3

SDI Research and Development Strategy

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SDI Research and Development Strategy

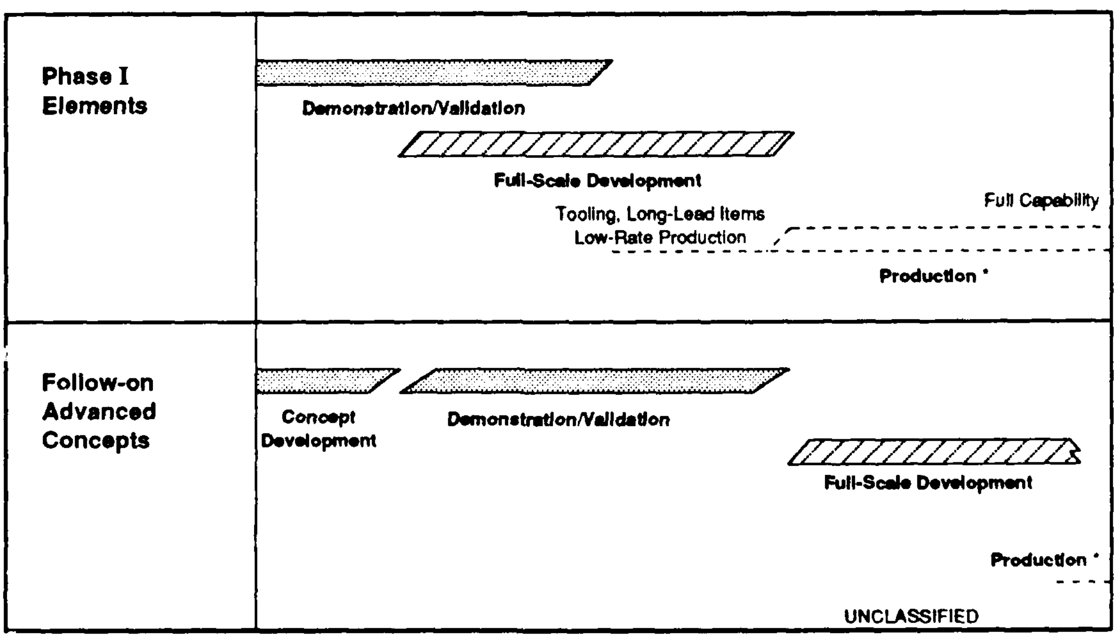
This chapter describes the research and development (R&D) strategy of the SDI Program: to conduct an overall R&D program that maintains a balance between near-term and longer-term technologies. The chapter addresses how the strategy supports planning for a deployment decision and the impact of budget cuts on the strategy. Also, the structure of the SDI Program is explained to show the relationship among projects, programs, and planned deployment phases.

3.1 Balanced Approach

The balanced approach to developing a strategic defense system (SDS) is based on technology improvements that continuously anticipate potential threats. This approach requires incremental improvements in three essential functional capabilities: sensing, command and control, and destruction of enemy ballistic missile threats.

The notional schedule for this approach is illustrated in Figure 3-1. The schedule shows the intended balance between near-term and longer-term technologies. Specifically, demonstration and validation of Phase I elements and concept exploration of follow-on advanced concepts should be pursued in parallel.

Figure 3-1
Notional SDI Program Schedule



* If a decision is made to proceed with deployment

This balanced R&D strategy would allow the Strategic Defense Initiative Organization (SDIO), given available technology and resources, to enhance the system

to best satisfy mission requirements in the face of an evolving threat. The strategy therefore provides assurance that the SDS will stay ahead of potential threats.

3.2 Planning for a Deployment Decision

The strategy supports the Program's goal to have within the next 3 years a sufficient basis on which to make an informed decision on whether to proceed with deployment of strategic defenses. The program to support this goal must address key technology issues while complying with the Antiballistic Missile Treaty limits on testing. It is also extremely important that credible cost estimates be developed for the decision.

Progress in these areas is related to the funding provided. The impact of the funding reductions is discussed below.

3.3 Impact of Reduced Funding on Program Strategy

As shown in Figure 3-2, the funding appropriated for the SDI Program from FY 1985 through FY 1990 has been reduced to about three-fourths of the amount requested by the President. These budget reductions have had a deleterious effect on the SDI Program, causing schedule slippages, cancellation of contracts, premature down-selects between competing technologies and system designs, and increased technical risk. Additional funding reductions will result in further delays and reduce the likelihood of deployment of defenses in this century.

The most recent cut of approximately $1 billion in the Bush Administration's FY 1990 request has reduced SDI funding to the FY 1987 level in terms of constant dollars (i.e., the effects of inflation are removed). As a consequence, the Program suffered delays and costly stretch-outs.

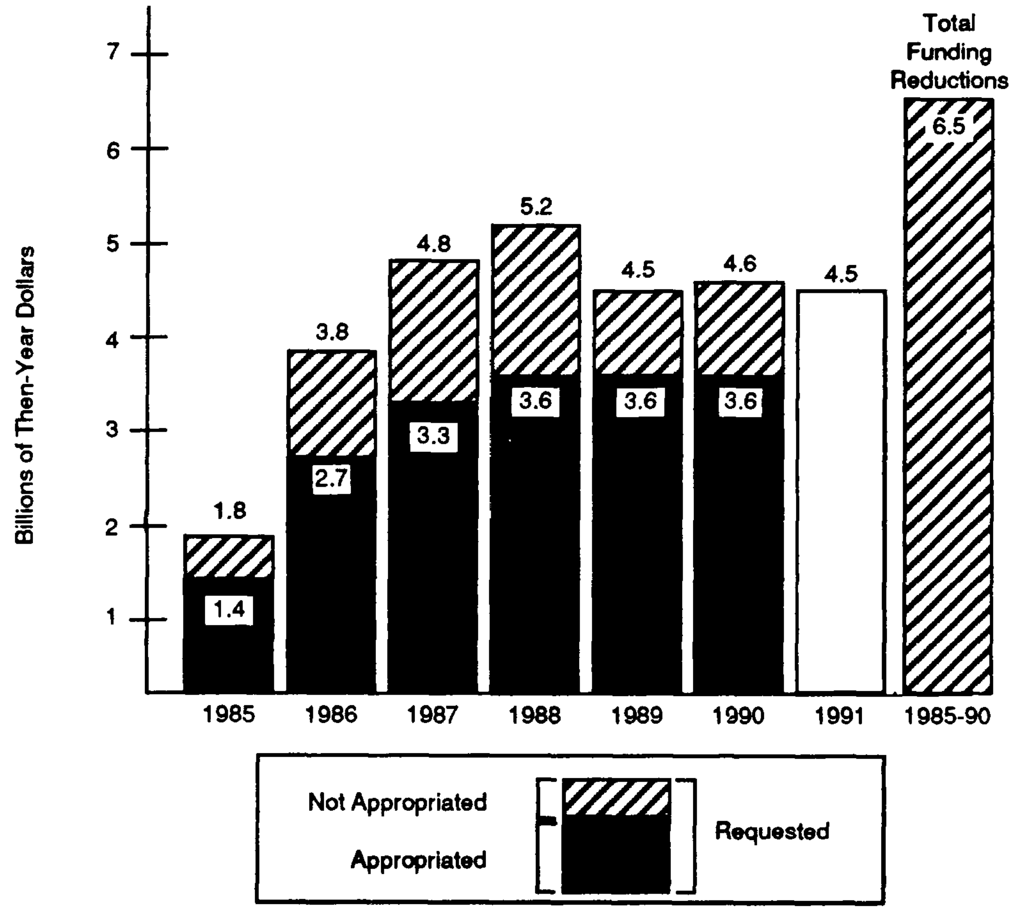
The 1983 Fletcher Commission provided some key insights regarding defenses that still guide our efforts in SDI. For example:

- The most effective systems have multiple layers. For this reason we continue to develop elements that can destroy ballistic missiles or their reentry vehicles in the boost/post-boost layer, the midcourse layer, and the terminal layer; these elements can be space-based or ground-based.

- Also, so that defenses can remain effective over time, they must be built to anticipate offensive responses; for this reason SDI includes not only development of the mature defensive technologies such as kinetic energy weapons, that can serve as the basis for a first-generation defense, but development of advanced technologies such as high-energy lasers as well.

Over time, however, SDI has not received the level of funding anticipated in the Fletcher Commission recommendations; this has had several effects. In the first 2 or 3 years we were forced to cut back and, in some cases, eliminate development of alternate defensive technologies; this resulted in a Program that was less robust in the face of possible technical setbacks. More recently, we have been forced to delay the whole Program.

Figure 3-2
SDI Program R&D Budget Requests vs. Appropriations
(By Fiscal Year)



In pursuing the SDI Program over the past 6 years, we have sought to maintain a balance between near- and far-term technology efforts to ensure that the Soviets cannot easily counter initial SDI deployments. Additional budget reductions could adversely impact longer-term efforts currently under way at the national laboratories and curtail efforts to improve the national advanced technology base.

In keeping with his commitment to reduce Department of Defense spending, the President directed that the SDI budget request be reduced by $1.3 billion in FY1991 (compared to the January 1989 Reagan budget request). This reduction resulted in greater but still manageable risk to the Program. However, significant additional cuts would threaten the basic goal of SDI.

The impact of the cumulative budget reductions has damaged the SDI Program infrastructure. Over the past few years, we have coalesced technology into an identifiable Phase I architecture and associated elements (i.e., a demonstration/validation program) plus several ground-based and space-based follow-on element concepts. We have awarded many multimillion dollar, long-term contracts,

and established appropriate program offices. We have now begun to dismantle some of this infrastructure, incur additional costs due to program stretch-out and contract renegotiation or termination, and suffer losses of skilled scientists and engineers.

The United States continues to have solid strategic and geopolitical interests in aggressively pursuing SDI, and strong Congressional support for this Program is vital.

3.4 Program Structure

To implement the R&D strategy, the SDI Program has been structured into groups of projects that are contained within the following functional areas: detect an attack; control, operate, and integrate the defense; engage and destroy attacking objects with interceptors of a Phase I defense system or advanced concepts of follow-on defensive systems; provide essential support to a prospective SDS; and furnish the system analysis, engineering, and testing capabilities necessary for system development.

The following discussion explains how the five program elements (PEs) in which SDIO receives funding relate to the above functional areas, various projects, and the phases of possible system deployment. For FY 1991, a sixth PE has been established to provide for full-scale development of Phase I, Strategic Defense System.

The projects that support detection are in the Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA) PE, which provides the research and technology development efforts necessary to identify and validate various sensor concepts that operate along the missile flight path. The battle management part of the System Analysis/Battle Management (SA/BM) PE develops the Command Center (CC) and associated System Operation and Integration Functions (SOIF).

The projects that support engagement and destruction of attacking objects are contained in two other PEs—Kinetic Energy Weapons (KEW) and Directed Energy Weapons (DEW). The KEW PE focuses principally on the interception and destruction of ballistic missiles or their reentry vehicles through the use of hit-to-kill projectiles. Both space-based and ground-based kinetic energy concepts are being investigated. Some of the kinetic energy concepts have been designated as Phase I interceptors because of their technological maturity. Certain efforts associated with developing and integrating on-board sensors and control components are contained within appropriate KEW projects. Other kinetic energy concepts may be used later to augment or upgrade the Phase I interceptors. The DEW PE provides the research and technology development required to identify and validate the most promising directed energy concepts, including ground- and space-based lasers and neutral particle beams. These concepts are being considered for follow-on defensive systems to perform interactive discrimination, engagement, and destruction functions.

Projects that entail research to support all defensive concepts are contained in the Survivability, Lethality, and Key Technologies (SLKT) PE, which develops technologies that support power needs, launches into space, survivability, lethality, and materials and structures.

Innovative science and technology (IST) and small business innovative research (SBIR) projects also create new and advanced, high-payoff technologies. These projects are funded by the SATKA, SA/BM, KEW, DEW, and SLKT PEs.

Systems analysis and engineering capabilities necessary for system development are contained in the analysis and engineering projects of the SA/BM PE. These projects provide technical guidance and support activities for the demonstration and validation of

Phase I elements and for follow-on system concepts. Research activities such as the National Test Bed as well as other experimental platforms (e.g., the Airborne Surveillance Testbed) support the integrated testing that is necessary for technology validation and system development.

Figure 3-3 shows the correlation of functional areas, activities, and related key projects with the PEs and phases of possible system deployment. Chapter 4 describes significant progress of the SDI Program, and Chapters 5 through 8 provide details of the near- and longer-term technology projects of the SDI Program.

Figure 3-3
Correlation of Major Program Activities
With Projects, Program Elements, and Possible Deployment Phases

Function	Activity	Key Projects	Program Element	Possible Deployment Phase (Initial or Follow-on)
Detect	Sensors	BSTS SSTS GSTS GBR	SATKA SATKA SATKA SATKA	Initial Initial Initial Initial
Control, Operate, and Integrate	BM/C3	CC/SOIF	SA/BM	Initial
Engage and Destroy	Strategic Defense Interceptors	Brilliant Pebbles[b] GBI SBI[c]	KEW KEW KEW	Initial Initial Initial
	Theater Interceptors	Theater Defense	KEW	[a]
	Follow-on Advanced Concepts	HEDI HVG GBL SBL NPB Acquisition, Tracking, Pointing	KEW KEW DEW DEW DEW DEW	Follow-on Follow-on Follow-on Follow-on Follow-on Follow-on
Support	Key Technologies	Survivability, Lethality, and Target Hardening	SLKT	[a]
		Power and Power Conditioning	SLKT	[a]
		Space Transportation	SLKT	[a]
		Materials and Phase I System Structures	SLKT	[a]
Analyze, Engineer, and Test	System Analysis, Engineering, and Testing	Phase I Systems Engineering	SA/BM	Initial
		SDS Engineering and Support (Producibility and logistics, advanced architectures)	SA/BM	[a]
		National Test Bed	SA/BM	[a]
Manage	Management	Program Management	All PEs	[a]

[a] Either supports all phases or is not associated with a specific phase.
[b] Also has a detection function.
[c] SBI, a specific type of space-based interceptor, is a backup to Brilliant Pebbles.

Chapter 4

Significant Progress in SDI

Chapter 4
Significant Progress in SDI

Since its inception, the SDI Program has made significant progress on all fronts. The fact that this progress has been achieved across a broad range of technologies shows that the Program has been well balanced with respect to near-term as well as longer-term applications. In addition, the accomplishments reveal how technological improvements have been used to reduce the costs of prospective strategic defensive systems while at the same time enhancing their potential effectiveness. In summary, the SDI Program has resulted in the formulation of:

- A Phase I architecture that will meet the requirements for strategic defense, based on technically achievable sensors, command and control capability, and interceptors

- Reasonable cost projections for such a system

- A set of technology development projects and a cohesive basic research program that support Phase I as well as systems that could employ advanced concepts such as lasers and neutral particle beams

- A national strategic defense research and development infrastructure, staffed with extremely talented and dedicated professionals, that stands ready to resolve the remaining technical and engineering issues.

The SDI Program has had a positive impact on virtually every military-oriented state-of-the-art technology program. In addition, technology spinoffs have contributed to other government agencies and commercial activities.

The major technical and system achievements are addressed in this chapter. Detailed descriptive material on the Strategic Defense System (SDS) elements, follow-on concepts, and theater defense can be found in Chapters 5 through 8. A discussion of technology spinoffs from the SDI Program is provided in Appendices D and E.

Figure 4-1 provides a year-by-year overview of the increasing number of major technical achievements of the SDI Program. The growing number of tests and experiments demonstrates that the Program is moving away from paper feasibility studies, laboratory work, and infrastructure development which characterized prior years. The Program is now moving into the testing of hardware, thus capitalizing on SDI investments. In addition to these technology achievements, the projects that support the initial elements of a system have made significant progress. Figure 4-2 provides an overview of this progress.

Figures 4-1 and 4-2, as well as the material that follows, show that SDI research is an excellent investment. That is why, in an era of scarce defense resources, the President is so supportive of the Program. We plan to continue to show impressive results. Significant technological advances that occur in the future will be exploited to further reduce the cost and improve the performance of a prospective SDS.

Figure 4-1
Major SDI Technical Accomplishments and Near-Term Plans

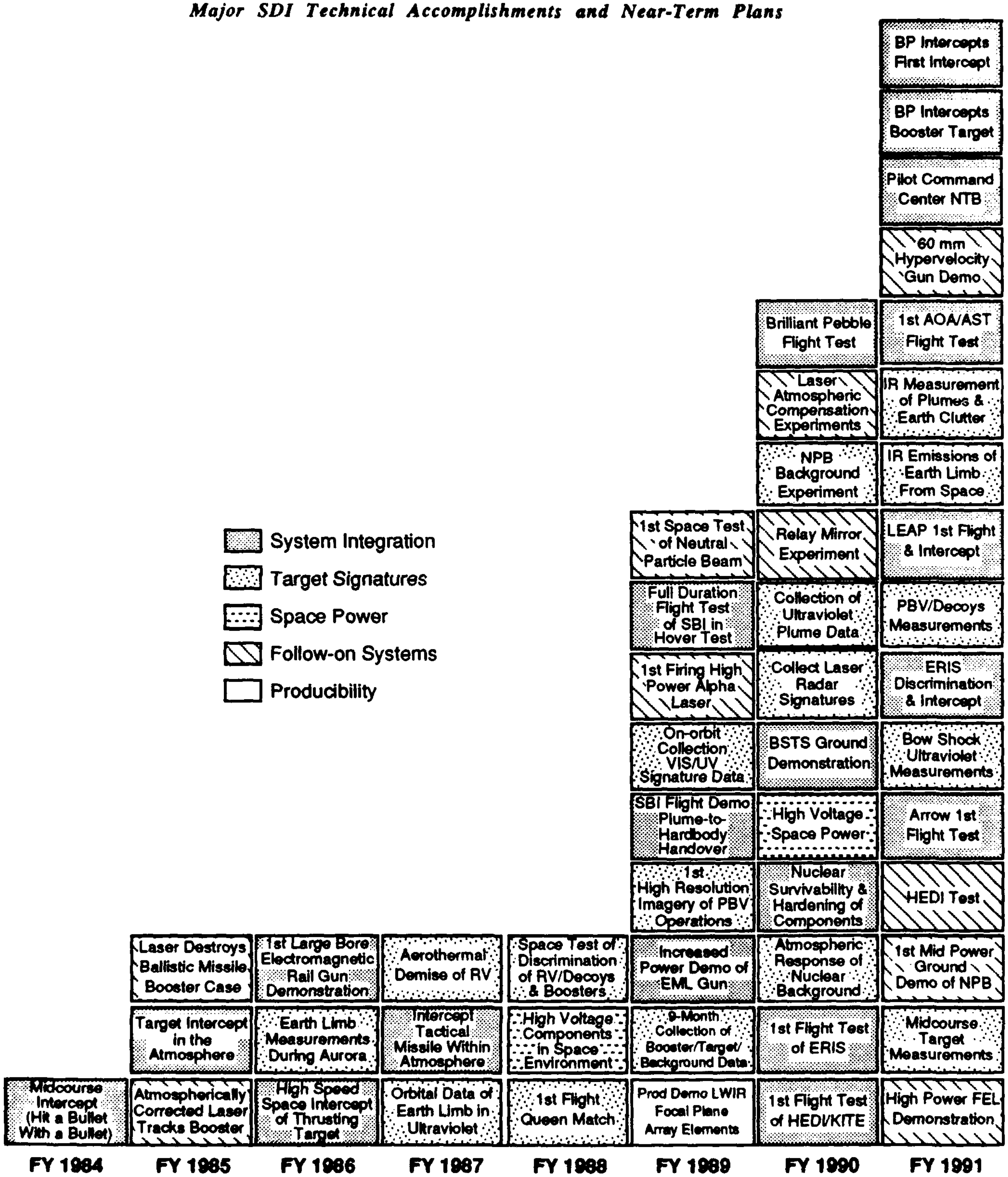


Figure 4-2
Overview of System-Level Progress for Initial Elements Since 1984

ELEMENT	PROGRESS	IMPACT
BSTS (Boost Surveillance and Tracking System)	• Project formulation initiated in 1984 as evolution of existing surveillance technology/platforms • Demonstration/validation of critical subsystem commenced in FY 1987 • Sensor focal plane producibility shows order-of-magnitude advances	Improved capability for detecting missile launches and tracking boosters compared to existing systems
SSTS (Space-Based Surveillance and Tracking System)	• Requirements identified and concept definition studies initiated in 1984 • Midcourse Sensor Study completed in FY 1988 • Revision of SSTS optics and cost reduction initiated in FY 1988	Provides surveillance/ discrimination capability in highly stressing midcourse tier
GSTS (Ground-Based Surveillance and Tracking System)	• Initial feasibility study completed in FY 1984-85 • Completed utility/technology study in FY 1986-87 • Milestone I approved and demonstration/validation contract initiated in FY 1988	Improved understanding of late midcourse discrimination capability required to isolate reentry vehicle clusters
GBR (Ground-Based Radar)	• Terminal Imaging Radar project led to GBR formulation in 1988 • Solid-state phased-array project transceiver modules initiated • Microdynamics algorithms development initiated in 1988	Identifies way to augment late midcourse "high traffic" discrimination and handover to interceptors
SBI (Space-Based Interceptor)	• Hardware completed to reduce kill vehicle weight by a factor of 5 • Spacecraft designed to reduce assembly and test from 60 to 6 weeks • Hardware/software data provided to support cost reduction of 80 percent	Initial space-based element carrier vehicle approach led to current interceptors; now a backup to the Brilliant Pebbles concept
BP (Brilliant Pebbles)	• Concept formulation initiated in 1987 as a result of SBI advances • Ground tests of several key components performed in 1988, 1989, and 1990.	Provides cost-effective space-based element, capable of independent operation, for boost/post-boost intercepts
GBI (Ground-Based Interceptor)	• Completed U.S. Army Kwajalein Atoll launch facility • Conducted launch complex checkout • Completed initial preflight validation of launch scenario	Ground-based exoatmospheric interceptor developed to meet Phase I SDS midcourse tier requirements
HEDI* (High Endoatmospheric Defense Interceptor)	• Wind tunnel tests proved feasibility of nose tip/window cooling, acceptably low boresight errors, shroud removal, and aerodynamics • Successful ground tests and simulations verified warhead and flight control performance prediction • Conducted first flight test of HEDI/KITE in 1990	Demonstrated feasibility of endoatmospheric segment of terminal-tier defense
CCE (Command Center Element)	• Command Center Element concept defined in FY 1988 • Experimental Version 88 battle management simulations completed • Pilot Command Center test bed program initiated in FY 1990 at the National Test Facility	Creation of battle management capability; provides for human-in-control and integration of system operation

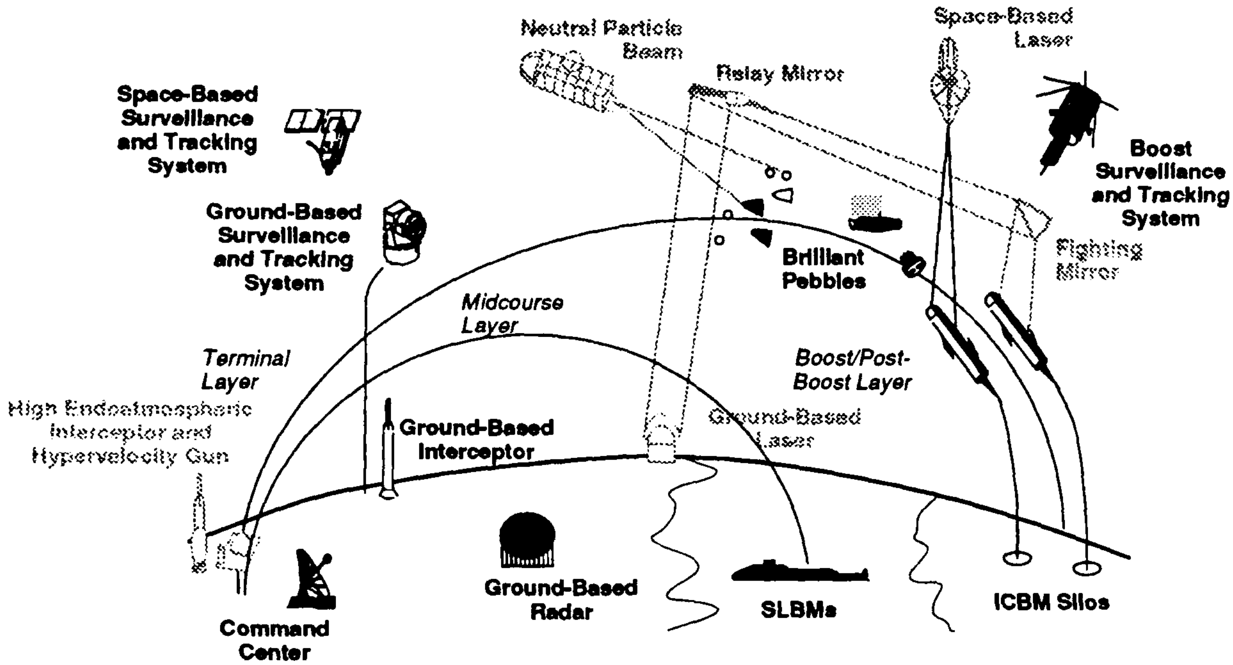
* Promising terminal-tier interceptor concept.

4.1 System Analysis/Battle Management Progress

The major work on architectures, the definition of an affordable system, and command and control have taken place in the System Analysis/Battle Management program. The Phase I architecture selected is consistent with the findings and

recommendations of the 1984 Fletcher Study on SDI. Subsequent studies have confirmed that it is a sound approa... It is a two-layer system consisting of both ground- and space-based interceptors and sensors and their supporting systems. Figure 4-3 shows Phase I and potential follow-on architecture elements.

Figure 4-3
Phase I and Potential Follow-on Architecture Elements



Phase I Elements are shown in Bold.
Potential Follow-on Elements are shown in Background.

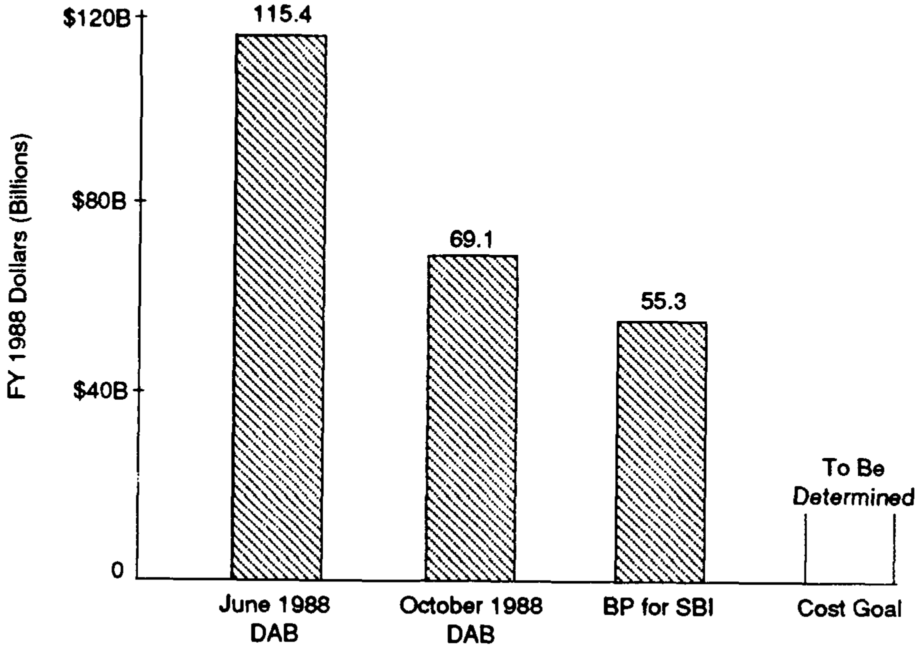
Projected acquisition costs of a Phase I system decreased in prior years from estimates that exceed $100 billion (in FY 1988 dollars) to approximately $69 billion. Refinements made this past year, principally as a result of incorporation of Brilliant Pebbles for space-based interceptors, have resulted in further reducing total costs of Phase I by 20 percent from $69 billion to approximately $55 billion (in FY 1988 dollars). These costs may be reduced even further, as suggested by our lower but yet undetermined final cost goal for the system in Figure 4-4.

Much progress has also been made in ensuring that defenses can be integrated and managed, always with human-in-control, and that they are survivable.

- The National Test Bed (NTB) has been established to develop, test, and validate strategic defense concepts and software.

- We are building high-fidelity end-to-end simulations that allow defense concepts to be tested against a variety of realistic threat models. This effort provides a basis for the development of command and control concepts and permits early user involvement.

Figure 4-4
Phase I Cost Comparisons



- An early version of a command center was successfully demonstrated at the Army Advanced Research Center. This program indicated that, with man-in-the-loop, there is sufficient time to assess, react, and engage attacking missiles throughout the battlespace.

- We have established a system software program to address the large- scale integration of software for a defensive system. The initial focus of this activity will involve integration of system simulation modules at the National Test Facility in Colorado Springs, the NTB's hub.

- To ensure that systems can operate reliably in the adverse environments caused by nuclear weapon detonation, we validate the survivability of system components, such as electronics, optics, and structures, through experiments on underground nuclear tests.

- Red-Blue Team analyses are conducted to examine the ways in which an attacker may try to defeat the defenses, and to establish effective measures to offset those attempts. Results are then fed back into efforts to design both the system and its operational concepts.

One of several significant demonstration and validation activities being undertaken in FY 1990 at the National Test Facility and the Army Advanced Research Center is the Pilot Command Center (PCC). The PCC will be used to model the command center functions and the human interface. FY 1991 plans are to experiment with sensor management techniques while, for the first time, introducing a physical representation of a modular command center. Mobile, modular command center facilities are considered the most cost-effective approach to ensuring wartime survivability of command and control.

4.2 Sensors Progress

To intercept a missile or reentry vehicle (RV), defenses first must detect, discriminate, acquire, and track the targets under a variety of conditions. Early in the SDI Program we established, and we continue to operate, a broad-based program to collect target signatures. This program includes numerous sounding rockets and rocket-launched satellites to put up sensors to view targets and decoys against different earth and space backgrounds. It also includes various airborne, shipborne, and ground-based sensors to collect signature data. (Examples of airborne platforms are an NC-135A equipped with sensors that operate in the visible through long-wavelength infrared bands and a Learjet equipped with ultraviolet through medium-wavelength infrared sensors.) Further, we have an aggressive program to explore and develop passive, active, and interactive discrimination technology. This program is supported by activities that build and test various decoys and penetration aids to see what will stress the system. Some specifics will illustrate our accomplishments and plans in these areas.

- In the 1980s our Delta 180 series detected, acquired, and tracked numerous objects including boosters, RVs, and decoys.
- In 1988 we collected our first infrared data on foreign targets in the Queen Match flight, and conducted many sounding rocket tests to evaluate decoys, countermeasures, and the effectiveness of discrimination.
- In 1989, in the JANUS experiment, we used high-resolution infrared imagery to collect target signatures of post-boost vehicles (PBV).
- In 1990 we will demonstrate that we can detect boosting targets of all intensities against a variety of earth backgrounds.

Development of the Boost Surveillance and Tracking System (BSTS) missile launch warning satellite is proceeding as planned. The system is scheduled to enter full-scale development (FSD) in FY 1991, subject to a successful ground demonstration in FY 1990. BSTS is essential to the national mission of tactical warning/attack assessment and other non-ABM missions. However, its role as a critical node to strategic defense has diminished with the adoption of Brilliant Pebbles. The first launch of an FSD vehicle is planned for the mid 1990s.

Development of the Space-Based Surveillance and Tracking System (SSTS) is also proceeding. The SSTS uses long-wavelength infrared (LWIR) to detect and track RVs and decoys in space. The role of SSTS as part of Phase I is being reassessed because of Brilliant Pebbles' potential for independent operation. Nevertheless, the technical challenge of assuring that LWIR sensors can be cooled sufficiently to permit effective operation in space remains. Specifically, the Prototype Flight Cooler is the least developed and presents the highest risk of all components for SSTS. The cooler will be evaluated and tested in FY 1991.

An important milestone for the Ground-Based Surveillance and Tracking System (GSTS) during FY 1989 was establishing its role as a cluster (group of RVs) tracking sensor for Phase I. Studies showed that GSTS could provide early-attack characterization capabilities to support RV impact point prediction. Early cluster tracking supports important system battle management decisions and strategy selection. GSTS provides an on-demand, ground-based supplement to other sensors.

During the formulation period in the SDI, it was recognized that new radars capable of overcoming the limitations of previous ballistic missile defense ground-based radars (GBR) would have to be developed. Accordingly, the GBR project was initiated in 1984. To demonstrate the capabilities of the radar to perform as predicted, a GBR-X will be built at Kwajalein Atoll. Delivery of the first assembly is planned for 1992. The GBR-X will have an innovative dual field-of-view antenna design, which will allow for support of a diverse set of experiments, allow for further radar technology development, and enhance the missile test range.

Many technology projects support the development of sensors. The most significant progress has occurred in signal processing, passive sensors, and manufacturing technology. The signal processing, passive sensor, and manufacturing accomplishments are described in Figures 4-5, 4-6, and 4-7.

Figure 4-5
Signal Processing Accomplishments

ACCOMPLISHMENTS	IMPACT
• Radiation-hardened bulk complementary metal oxide semiconductor chips tested to 10 times required total dosage.	Survivable SDS sensors/interceptors
• High-speed, radiation-hardened, static random access memories (SRAMs) achieved at 64K size using silicon-on-sapphire process and tested to hardness required for space processors. • Development of 256K SRAM under way. • Development of a high-speed (200 million operations per second (MOPs)/node), radiation-hardened 32-bit microprocessor under way for spaceborne computer with 2 to 4 times the throughput of previous Generic Very High Speed Integrated Circuit spaceborne computer prototype. • Fault-tolerant, compact three-dimensional computer with an ultimate processing speed of 160,000 MOPs is under development.	Compact high-capacity, fast, survivable space processor for sensor signal processing/battle management functions

In addition, many experiments designed to understand better the phenomenology of detecting and discriminating targets in space have taken place and are planned. Some highlights appear below.

- The SPIRIT I sounding rocket, launched in April 1986, collected data that characterized earthlimb emissions, an important issue for midcourse sensor system design and operation (e.g., SSTS, GSTS).

- The Visible Light/Ultraviolet Experiment (VUE) instrument began obtaining data in October 1989. VUE is to collect data for a minimum of a year. Principal data include visible and ultraviolet ballistic missile phenomenology, resident space objects experimentation, testing a satellite attack warning concept, and the range of natural backgrounds likely to face systems using this technology.

Figure 4-6
Passive Sensor Accomplishments

AREA	ACCOMPLISHMENTS
Optics Technology Impact: New mirror materials and fabrication processes produce high-resolution, image-quality optics for space-based sensors that are survivable in nuclear environments.	• Hardened large aperture beryllium (Be) mirrors with wide field of view (FOV) for large coverage and improved off-axis rejection were developed. • Hot isostatic pressed 9-inch mirror fabricated to near optical figure limits. • Tested forward acquisition sensor Be mirrors at cryogenic temperatures required to detect targets. • Silicon carbide-coated mirror survived simulated nuclear environment.
Cryocooler Technology Impact: Cooled sensor detectors for high-efficiency, low-noise performance detection/ discrimination of cold midcourse targets require compact space refrigerators to cool components to near-absolute zero temperatures.	• Demonstrated two three-stage cooler concepts for cooling focal plane arrays and wide FOV optics. • Proof-of-concept for magnetic and sorption cooling principles demonstrated. • First-ever nonmoving parts cryocooler demonstrated improvements of factor of three cool-down time and factor of seven capacity at 15° Kelvin. • Demonstrated first-ever conduction magnetic cooling device using superconducting magnets.

Figure 4-7
Focal Plane Array Manufacturing Accomplishments

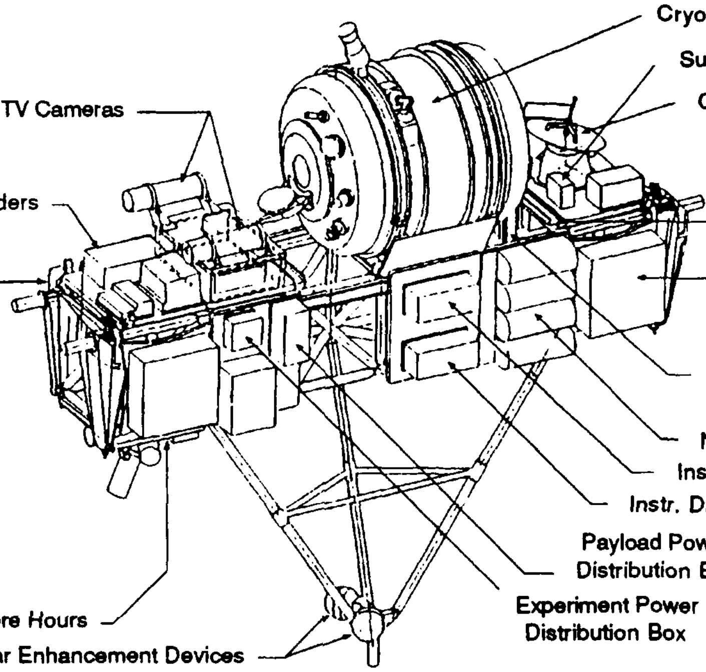
AREA	ACCOMPLISHMENTS		
Below-the-Horizon Sensing (e.g., BSTS)		Contractor A	Contractor B
	Project Goal (Yield)	1.50%	1.50%
	End Yield	10.3%	35%
	Cost per Pixel (formerly $400)	$3.17	$0.28
	Array Size (Number of Pixels)	64 x 32	128 x 128
Above-the-Horizon Sensing (e.g., SSTS and GSTS)	Technical Goal: Cost Goal:	Able to function in severe nuclear environment in space. Reduce from $100 per pixel to $1.00 per pixel.	

- The Delta Star spacecraft was launched in FY 1989. In the course of well over 100 separate mission operations, it observed a number of representative strategic and tactical activities and measured earth, atmosphere, and space background scenes important for SDS sensors and weapons. Multispectral measurements provided unique imagery. Delta Star also made significant contributions to understanding the effects of chemicals released in space, the degradation of spacecraft materials during a long-duration flight, and the natural earth background.

- The Infrared Background Signature Survey (IBSS) will observe and characterize the spectral and radiometric signatures of several space objects and phenomena critical to the design and operation of surveillance and intercept systems. These signatures include rocket plumes, the earth and its atmosphere, observables from fuel chemical releases, and other controlled

cases and normal Orbiter releases. The IBSS configuration is shown in Figure 4-8. The mission is manifested on the Shuttle as STS-43 with a launch date in 1991.

Figure 4-8
IBSS Configuration



- The shorter wavelengths of a laser radar permit high resolution with smaller apertures than other radars. Many high-resolution laser radar measurements have already been obtained. Our Firepond laser radar facility, the result of 4 years of development, began to measure target dynamics following target launches from Wallops Island with the successful Firefly flight in March 1990. A space-qualifiable laser radar suitable for discrimination of RVs from decoys is scheduled for delivery in 1992.

4.3 Kinetic Energy Interceptors Progress

Since the SDI Program commenced in 1984, the SDI interceptor effort has had two major thrusts: to develop an interceptor that would not require detonating a nuclear device and that could destroy hostile intercontinental and submarine-launched ballistic missiles as far from U.S. territory as possible, perhaps even before they deploy multiple RVs. Kinetic energy interceptors are intended to destroy incoming threats by direct impact, without the need for defensive nuclear warheads. Three major experiments have demonstrated that we now have the technology in hand to perform such intercepts.

- In 1984 we hit a "bullet with a non-nuclear bullet" using a ground-based interceptor and an on-board passive infrared sensor for terminal guidance to destroy a simulated reentry vehicle launched from a ballistic missile.

- In 1986 we validated guidance laws in space by destroying a thrusting target. Such guidance laws are necessary in order to intercept a ballistic missile in the boost portion of its trajectory.

- In 1987 the Flexible Lightweight Agile Guided Experiment demonstrated that a theater-type missile reentry vehicle could be intercepted in the atmosphere using a radar-guided interceptor.

The technology projects discussed below are designed to support possible future FSD decisions for Phase I and follow-on elements as well as theater interceptors.

The Brilliant Pebbles (BP) program is presently entering a multicontractor concept definition phase. During this 8-month period, industry will assess and define the baseline interceptor concept as developed by the Lawrence Livermore National Laboratory. BP achievements during FY 1989 include the following:

- Sensors, reduced in size and weight by approximately tenfold from their previous configuration, have been built and tested. The laser communications transmitter has been demonstrated in the laboratory.

- A passive sensor suite was flown on an SDIO experiment. In addition, the star tracker sensor used for BP navigation was flown.

- Our NC-135A and Learjet aircraft used calibrated radiometric sensors during flights for data collection in order to measure target signatures in the spectral bands of interest to the BP project.

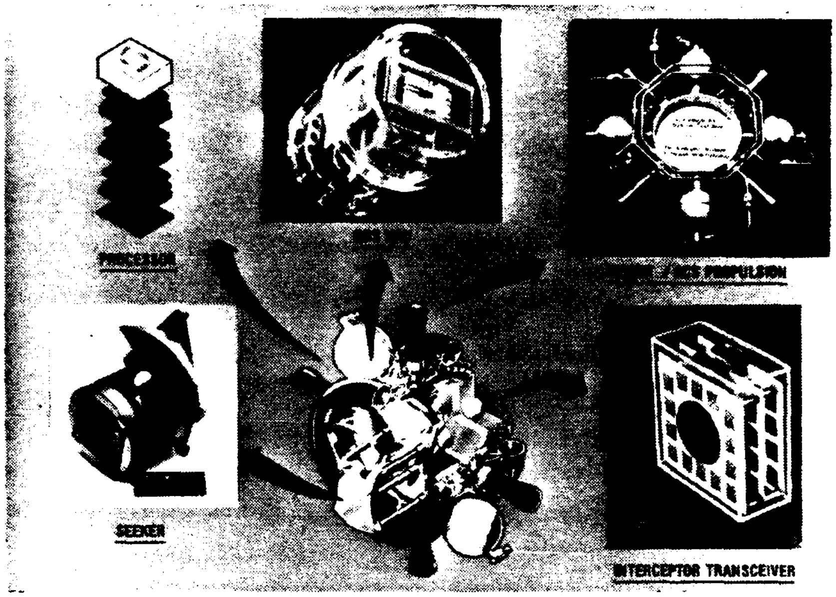
- Flight tests beginning in FY 1990 will include a series of interceptor flights to demonstrate BP subsystems in ground-launched ballistic flights. Intercept of a booster target by an experimental BP vehicle is planned in the near term.

The Space-Based Interceptor (SBI) is now a backup approach to BP. However, much of the SBI is relevant to the development of BP. For example, in a 1989 series of SBI hover tests conducted in the National Hover Test Facility, we demonstrated the full capability to acquire and track a rocket plume, then transition to tracking the rocket hard body. This capability is absolutely essential for boost and post-boost intercepts.

To perform the 1989 hover tests, we integrated a host of technologies. Figure 4-9 shows one example of an integrated technology development. The quartz rate sensor inertial measurement unit is used to track interceptor velocity, acceleration, and rotation. The divert and attitude control system propulsion unit is used to maneuver the kill vehicle to achieve a hit-to-kill. The interceptor transceiver provides secure two-way communication in a very small, lightweight unit. The seeker features lightweight optics and a cooled sensor array.

The Ground-Based Interceptor development project is structured to resolve technical issues facing the midcourse interceptor through the exploration of advanced concepts and technologies. Successful fabrication and ground testing of a scanning two-color LWIR seeker and a kill enhancement device to defeat midcourse countermeasures have been achieved. A fast cool-down cryocooler has been successfully ground tested. Also, preparations have been completed for the first functional test vehicle launch in FY 1990 from Meck Island at Kwajalein Atoll.

Figure 4-9
Integrated Hardware Technology Development



The High Endoatmospheric Defense Interceptor (HEDI) is the most mature concept being considered for terminal defense. It is a ground-based, hypervelocity, high-acceleration interceptor designed to destroy ballistic missile reentry vehicles high in the atmosphere. It is both a potential follow-on to Phase I and a backup to the Ground-Based Interceptor. The HEDI also has strong potential for theater defense.

In January 1990, the first HEDI/KITE flight test demonstrated our ability to effectively cool a terminal interceptor's forebody and sensor window. This demonstration showed that the sensors would not be disabled by heat from atmospheric friction. Until this demonstration, many in the technical community believed that effective window cooling could not be achieved. Figure 4-10 shows the readiness for launch of this first demonstration. During the remainder of FY 1990 and in FY 1991 we will prepare to conduct a second flight test to verify target acquisition and tracking functions, control and guidance systems, and seeker window survivability.

Hypervelocity guns (HVGs) utilize electromagnetic, electrothermal, or other advanced concepts instead of conventional chemical rocket propulsion to accelerate projectiles to ultrahigh velocities. The first large-bore electromagnetic gun demonstration was conducted in FY 1986. The current HVG project has two primary applications: terminal and space defense. For terminal defense, the emphasis is placed on building and demonstrating a large-scale test bed. This terminal defense test bed will establish the technical and conceptual basis for firing a projectile at speeds which will directly support space-based mission requirements.

The SDIO is examining, in coordination with NATO and other allied participants, appropriate technical alternatives for theater missile defense. This activity includes proposed theater defense architectures, critical technology requirements, identification of theaters, and the application of new technology efforts that can address problems peculiar to each particular theater of operations. Of particular interest are two

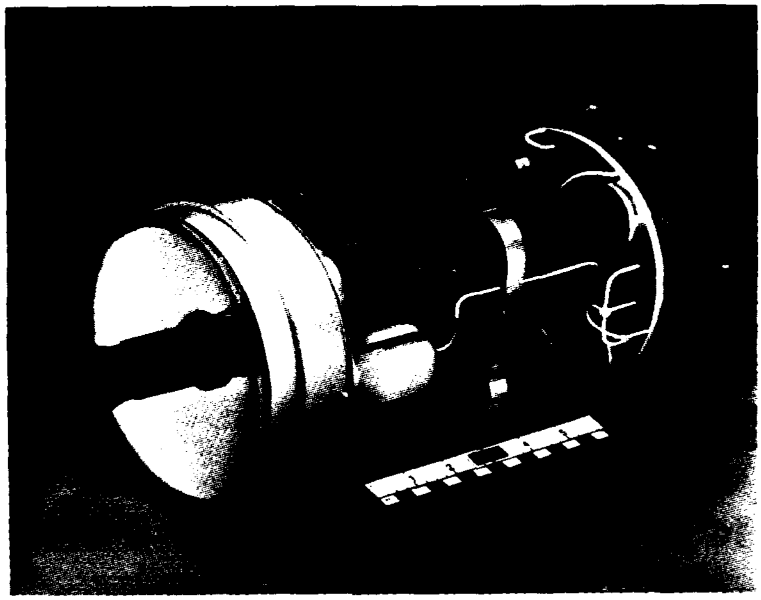
Figure 4-10
First HEDI/KITE Test Readiness for Launch

interceptor projects. The first, Arrow, is a cooperative experiment between the United States and Israel, and the second, Extended Range Interceptor Technology (ERINT) experiment, is a U.S. venture.

The Arrow experiment is designed to evaluate an Israeli design of a missile interceptor. The Arrow missile will soon demonstrate its capability to intercept a surrogate tactical ballistic missile (TBM). The first Arrow flight test will be conducted in FY 1991. The ERINT-1 experiment will validate a single-stage, solid rocket interceptor concept that can destroy TBMs in the atmosphere. Rocket sled tests of the ERINT-1 lethality enhancer warhead and fusing scheme were successfully completed in FY 1989.

A number of SDI technology programs are aimed at developing improved kinetic energy interceptors. The most significant of these is the Lightweight Exoatmospheric Projectile (LEAP) program. LEAP has made great strides in the miniaturization of interceptors by developing fully integrated kill vehicles weighing less than 3.5 kilograms (see Figure 4-11). One reason for such progress is the advancement in inertial measurement unit technology. The first small lightweight interferometric fiber-optic gyro weighing 430 grams has been demonstrated. The resonant fiber-optic gyro project has progressed to the prototype stage, with a goal of a 500-gram package and a cost of only $5,000 per unit. This gyro has performance capabilities that are comparable to that of the ring laser gyro, which weighs about 5 kilograms and costs about $30,000 per unit. Even smaller units that could weigh only 10 to 50 grams are being pursued.

Figure 4-11
LEAP Vehicle



The most recent developments include the preparation for hardware-in-the-loop and the hover- and flight-testing of the LEAPs in 1990 and 1991. Relying on the Commercial Launch Space Act of 1984, SDIO has procured flight launch services using standardized vehicles for more than 20 flights to gain resource efficiency.

4.4 Directed Energy Progress

Directed energy devices possess unique characteristics such as near-speed-of-light delivery, long-range, and multiple-shot capability. These characteristics could enable the devices to perform all of the classic strategic defense roles, ranging from booster and post-boost vehicle destruction to interactive discrimination of advanced decoys in the midcourse layer. In addition, the advanced sensing capabilities of these devices could enable detection and tracking of the missile, PBV, or deployed RVs.

Progress in directed energy technologies has been impressive. The key issues being examined are target acquisition, pointing and tracking, generating high power lasers and particle beams, and beam lethality.

- In 1985 we demonstrated at low power the capability to both track a rocket in space and propagate a laser beam through the atmosphere without significant distortion. In several other experiments, we proved lasers are lethal weapons for destroying both solid and liquid propellant missiles.

- In 1986 our first particle beam experiment irradiated a miniature RV with a high intensity proton beam. The results indicated that the conventional explosives contained in an RV can be detonated by such beams.

- Early in the program many experts had stated that building large optics would be impossible and prohibitively expensive. In 1988 we built a high-quality mirror, the first large-diameter segmented mirror with a surface that is controlled electronically. That mirror will be integrated into a ground test in 1991.

- In 1989 the Alpha chemical laser for the first time produced a high-power beam when fired in its space test chamber in Southern California (see Figure 4-12). This milestone in the space-based laser program is being used to validate the technology, computational methods, and fabrication processes necessary for scaling chemical lasers, configured for space basing, to power levels required for a strategic defense.

Figure 4-12
Ground Test Site of Alpha Laser

- In 1989 our Beam Experiment Aboard Rocket (BEAR) conducted the first test in space of a neutral particle beam (NPB). It employed a relatively lightweight power supply which can be packaged for space operation. It demonstrated that complex directed energy weapons could be reliably operated in space. The BEAR payload is shown in Figure 4-13.

- In February 1990 we launched the first long-term directed energy space experiments from Cape Canaveral. The 2-1/2-year Low-Power Atmospheric Compensation Experiment, known as LACE, will measure atmospheric distortion effects on laser beams. The 1-year Relay Mirror Experiment, known as RME, will demonstrate the relay element of a ground-based laser. LACE and RME were launched together aboard a commercial Delta II launch vehicle (see Figure 4-14).

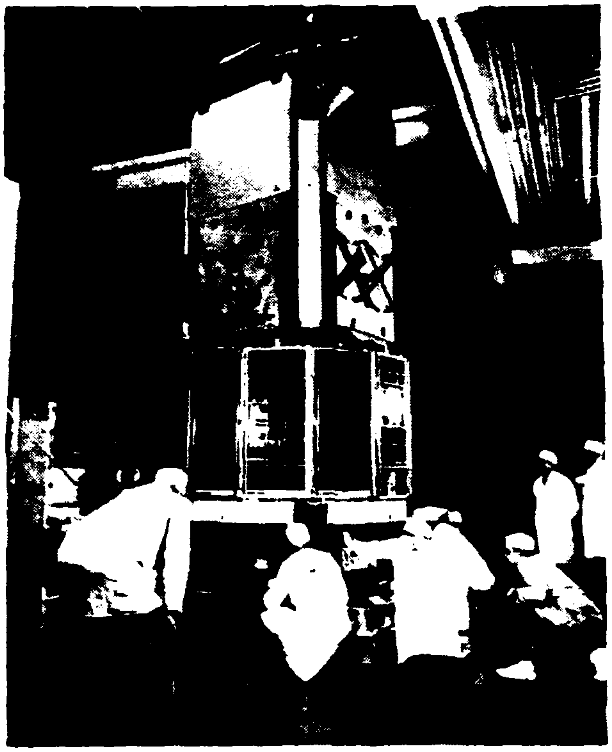
Figure 4-13
BEAR Payload

- The Talon-Gold ground test demonstrated our ability to place a beam on target very accurately. The next challenge is to do it in space—the Starlab experiment currently planned for 1992. In this experiment we seek precision equivalent to firing a laser from high above the Empire State building to hit a volleyball on a California beach.

In FY 1991 we plan to perform a pulsed, high-power concept demonstration of a free electron laser device. We also are planning a full power test of the NPB ground test accelerator at Los Alamos.

In FY 1991 we will continue construction of the technical facilities for free electron laser research at White Sands Missile Range in New Mexico. When completed (in approximately FY 1993), it will be available to support the high-power laser experiments needed to validate the concept.

Figure 4-14
LACE and RME



4.5 Survivability, Lethality, and Key Technologies Progress

Much progress has occurred in technologies critical to many SDS elements. Key technologies focus on survivability, lethality and target hardening, power and power conditioning, materials and structures, and space transportation.

Many noteworthy survivability achievements have taken place. The thrust of these achievements is to enhance the ability of a U.S. defensive system to perform its mission even in the face of attacks intended to suppress or destroy portions of the defense. For example, the hardness of shields against debris and lasers has been increased significantly, the deformation of mirrors due to nuclear effects has been greatly reduced, and laser-hardened space components have been developed. The Disko Elm underground nuclear test conducted in 1989 was applicable to ground- and space-based interceptors and sensors. It explored technologies for the survivability of components such as lenses, filters, beryllium mirrors, and electronics. Another underground nuclear test is slated for 1990 to examine such things as the nuclear survivability of mirror and window coatings and materials. These and other nuclear tests, together with a series of integrated survivability experiments and demonstrations of active survivability techniques, are intended to show that SDS survivability can be achieved. Additional survivability accomplishments are shown in Figure 4-15.

The lethality and target hardening project was established to determine vulnerability levels for current and responsive threats. Early knowledge of threat vulnerability supports weapon-concept feasibility decisions and improves our ability to develop highly effective weapon systems at minimum cost. Figure 4-16 highlights key

Figure 4-15
Survivability Accomplishments

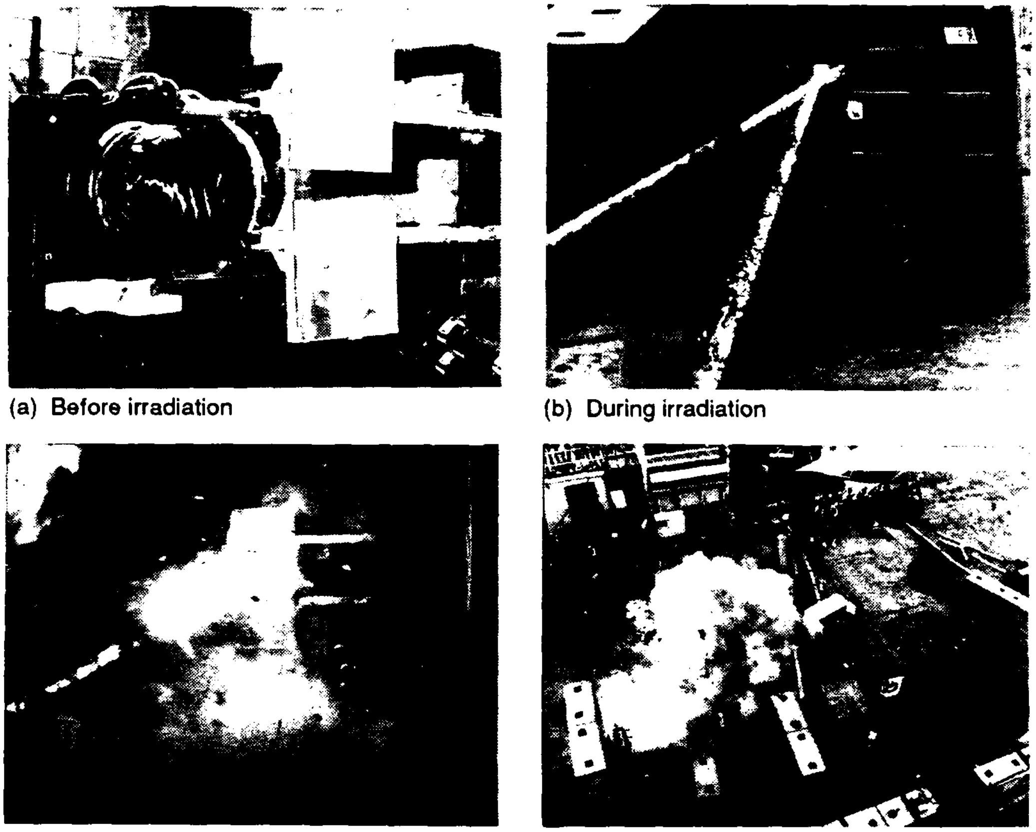
SUBSYSTEM	ACCOMPLISHMENT	IMPACT
Sensors	• Demonstrated hardened sensor/seeker array technology	Increased nuclear hardness tenfold; reduced nuclear radiation induced sensor noise tenfold
	• Demonstrated producible filters with 10,000-fold laser protection factor	Increase sensor protection against laser damage and jamming
	• Developed processing schemes to mitigate nuclear environment effects on sensor output	Minimum hardware impact
	• Demonstrated tenfold improvement in mirror hardness	Extends physical survivability beyond Phase I threat environment goals
	• Developed protective optical coatings with a fivefold increase in hardness	Protects mirror and lens performance enhancing coatings
Computers and Electronics	• Demonstrated a hundredfold increase in computer component hardness	Static random access memory chips from five vendors
	• Demonstrated hardened memory modules to satisfy Phase I requirements	Provides factor of five safety margin
	• Demonstrated computer recovery within milliseconds	Satisfies program goals
Shields	• Reduced weight of laser/pellet shield	30% reduction achieved
	• Increased laser shield hardness	Fivefold increase achieved
	• Demonstrated feasibility of lightweight advanced debris shield	50% lighter than conventional designs
Thermal Control	• Developed lightweight laser-hardened insulation material	Provides twofold increase in laser hardness
	• Developed advanced structure materials	Provides tenfold increase in laser hardness

Figure 4-16
Lethality/Target Hardening Accomplishments

WEAPON	ACCOMPLISHMENT
Kinetic Energy	• Aerothermal kill (during reentry) feasibility demonstrated • Mission kill of PBVs, boosters, and defense suppression threats for space-based interceptors demonstrated • Minimum fragment mass and distribution for assured lethality against RVs demonstrated
Lasers	• Thermal laser lethality demonstrated destruction of boosters hardened by active (rotating) and passive (highly reflective skin) measures • Mid-Infrared Advanced Chemical Laser test against graphite epoxy overwrapped PBV tank demonstrated effects of hardened components
NPB	• Laboratory experiments established failure level for PBV guidance and control • Signatures for particle beam interactive discrimination demonstrated

lethality accomplishments for various weapon concepts, while Figure 4-17 illustrates recent lethality tests for a laser weapon. Future kinetic energy experiments will assess the minimum mass to achieve aerothermal kill of an RV and the effects on neighboring RVs of detonations aboard a PBV.

Figure 4-17
Irradiation of Overwrap Hardened Titanium Sphere



(a) Before irradiation
(b) During irradiation
(c) At instant burst
(d) Post burst

Power systems must operate reliably while meeting stringent weight, volume, survivability, and cost constraints. Initial power project research focused on component development, but more recently the integration of these components into complete subsystems is demonstrating the necessary feasibility. For example, in 1987 a rocket-borne experiment collected data on the operation of high-power electrical components as a function of altitude, atmospheric pressure, and orientation to the earth's magnetic field. The data indicated feasibility to operate exposed high-voltage subsystems in space. As a result, high-power space platforms such as lasers, particle beams, and electromagnetic guns might require minimal insulation, thus reducing weight and cost. A follow-on rocket-borne space experiment is scheduled to be conducted in FY 1990. Other power highlights are depicted in Figure 4-18.

The materials and structures (M&S) project draws upon the nation's technology base in structured materials and technology, tribomaterials, space environmental effects, structural dynamics, and superconducting devices. Contracting with SDI prime contractors for M&S technology inserted demonstrators that focus on Phase I system requirements, emphasizing structures technology for directed energy weapons platforms, and the many M&S accomplishments illustrated in Figure 4-19 will enhance the performance and reduce the technical and economic risk of Phase I and follow-on systems.

Figure 4-18
Power and Power Conditioning Accomplishments

ACCOMPLISHMENT	IMPACT
• Component level tests simulating laser, nuclear, pellet, and high-power microwave attack.	Survivability of space power for Phase I systems
• Successful test of 1-megawatt hyperconducting generator exciter.	Establishes feasibility of nation's first space-qualifiable generator
• Successful generation of 5 megawatts of power with magnetohydrodynamic generator.	Demonstrates that lightweight multimegawatt power is possible
• Successful generation of first high-power klystrode.	Enables practical power conditioning for space-based beam weapons
• Low temperature superconductor operated at world record current of 260,000 amps.	Enables cost-effective superconducting magnetic energy storage

Figure 4-19
Materials and Structures Accomplishments

ACCOMPLISHMENT	IMPACT
• An Integrated Structures Model to assess structural response of platforms/vehicles was developed and applied to the LEAP technology hardware.	Improved acquisition/tracking
• Analytical techniques for assessing passive damping of structures were used to qualify materials for LACE/RME spacecraft.	Improved directed energy weapon pointing
• Lightweight, stiff, and high-performance structural members (trusses, tubes, etc.) have been fabricated from advanced thermoplastic composites.	Compact low-cost space platforms
• A 40% lighter-weight advanced composite GBI kill vehicle structure was ground-tested.	Higher velocity interceptors
• A graphite tube reinforced thermoplastic interceptor housing has been tested at the National Hover Test Facility.	Higher velocity interceptors
• The active materials experiment on Delta Star provided telemetered materials data for thousands of hours on orbit.	Improved spacecraft lifetime
• Metal-based optical baffle with inherent nuclear hardness has demonstrated less than 1% reflectance as designed.	Improved HEDI accuracy
• HEDI window blank of optical quality sapphire is undergoing installation on a flight vehicle.	Survivability of optics
• Automated weaving process for nozzle fabrication was demonstrated to be cost effective in a static firing of a subscale braided carbon-carbon interceptor booster.	Improved booster performance
• A first-ever high-temperature superconductor microwave filter suitable for communications and radar systems has been demonstrated with 20 times better performance than state of the art.	Improved command and control

The focus of our advanced launch activities is on definition and development of enabling technologies for the next generation of space launch vehicles. Much progress has been achieved in this area, such as in low-cost engine definition. Key accomplishments appear in Figure 4-20.

Figure 4-20
Space Transportation Accomplishments

ACCOMPLISHMENT	IMPACT
• Low-cost liquid engine components defined/designed and currently in fabrication.	Increased reliability, lower costs
• Demonstrated subscale clean (i.e., drastically reduced hydrochloric acid in the exhaust) solid propellant formation.	Reduced environmental impacts
• Demonstrated subscale components for electromechanical actuators oriented at replacing unreliable hydraulic systems for engine vectoring.	Compact, reliable, safe boosters
• New cryogenic tank material compatibility with liquid oxygen assured; 30% improvement in tank weight with higher strength.	Increased performance
• Demonstrated subscale tank fabrication using explosive-forming and spin-forming techniques.	Simplified manufacturing

4.6 Technology Transfer

This section highlights the tremendous potential the SDI Program has for technology transfer to other military missions. The Defense Department has identified many technologies as vital to the national interest, in general, and the U.S. defense posture, in particular. There is a substantial association between the SDI Program and these technologies.

The Innovative Science and Technology Office funds projects that promise "order of magnitude" improvements in technologies that could be used in the SDS. Figure 4-21 highlights these accomplishments. Other SDI-sponsored research, including Small Business and Innovative Research, is providing spinoffs in many scientific and technical fields with other government and commercial applications. These include computer, sensor, and semiconductor technologies; material sciences; optics; and medicine. Representative spinoffs from SDI-funded technologies are discussed in Appendix E.

Figure 4-21
Innovative Science and Technology Research Progress

PROJECT	IMPACT
Multiphoton laser pumping	Potential thousandfold increase in x-ray laser efficiency
Superconducting IR detector	Hundredfold lower noise equivalent power than HgCdTe
Water-clear diamond film	Transparent hardened optical coatings
Phased-array microwave source	10-gigawatt source for microwave beam
Solution propellant	Environmentally acceptable exhaust, on-site rocket fabrication
Inverted gallium arsenide layers	Three-dimensional microelectronics
Superconductive shift registers	World's fastest computer processing element
Single-crystal epitaxial silicon	Greatly reduced very large-scale integrated circuit features/increased circuit densities
Thin-film laser	World's smallest semiconductor laser
Atomic holograms	Instrument with resolution of individual atoms
Lightweight permanent magnets	Tenfold increase in flashover hold-off voltage of electrodes
Dynamic gallium arsenide memory cell	World's first fabrication (leads to high-speed processors)
High-current switch	World's first fabrication (leads to power conditioning hardware)
Atomic diagnostics	Tiny high-intensity light spot to probe strong-field phenomena
Silicon surface cleaning	Low-temperature process to enable three-dimensional circuits integrated
Analog-to-digital converter (5 bits)	First gallium arsenide radiation-hardened analog-to-digital converter
Computer routing optimization	Dynamic reprogramming of paths through arrays of computers for high-efficiency processing
Holographic missile tag	One-of-a-kind tag for treaty verification
High-energy oxidizer	Nonmetalized propellant that avoids sensor blocking
Electric propulsion	More efficient orbital transfer doubles payload mass to high orbit

Chapter 5

Initial System

Chapter 5
Initial System

The initial system, also referred to as the Phase I Strategic Defense System (SDS), is based on the original system concept and the two-layer architecture described in Chapter 2. The initial system consists of the following elements: Boost Surveillance and Tracking System (BSTS), Space-Based Surveillance and Tracking System (SSTS), Ground-Based Surveillance and Tracking System (GSTS), Ground-Based Radar (GBR), Brilliant Pebbles (BP), Ground-Based Interceptor (GBI), and Command Center (CC). Development of a backup to Brilliant Pebbles is continuing. This backup is known as the Space-Based Interceptor (SBI), a specific type of interceptor technology for the boost layer. Each of these elements is explained in detail in this chapter.

The results of the March 1989 Interim Requirements Review (IRR) indicated that sufficient progress has been made in the architecture studies to begin a transition to the engineering development of a system requirements base. The IRR recognized that the various elements of the SDS are at different stages of development. It also recognized that the more advanced elements will start to define specific design requirements for the less advanced elements to facilitate their integration into the SDS.

The remainder of this chapter summarizes the current status of the initial system, which will be presented in four sections:

- Systems Engineering—the integration of the various SDS elements
- Sensors and CC/SOIF—the sensors, command center, and SOIF (system operation and integration functions)
- Initial Kinetic Energy Projects—the interceptors
- System Validation—the roles of test and evaluation and the National Test Bed.

Each section will contain an overview of the concepts, projects, and key technologies involved.

5.1 Systems Engineering

The continuing goal of systems engineering (SE) is to design and implement a highly effective, deployable SDS. This goal necessitates a program adaptable to the changing environments of national priorities, funding, and the dynamics of existing and emerging technologies. The significant cost reduction (in 1988 dollars), identified during FY 1989 for an effective Phase I architecture, was made possible due to both the introduction of Brilliant Pebbles technology and the institution of an SE process that emphasizes element architecture efficiencies and integration with other system elements.

5.1.1 Phase I Systems Engineering

As both a technical and management process, SE ensures that the SDS design incorporates and integrates the full capabilities of all of the system's elements to produce a cost-effective SDS that satisfies the mission requirements. It guides the integration of technical efforts to produce a balanced program by effectively allocating requirements across the elements to produce a robust system. It provides a comprehensive framework of requirements and ensures that life-cycle costs and specialty engineering efforts are part of the initial design process. Thus, systems engineering is the critical process to ensure that research in technologies and architectures can be effectively and affordably brought together during the Phase I demonstration and validation (Dem/Val).

The Spaced-Based Architecture Study, completed in FY 1990, established the architectural interrelationships of the space-based elements. The SDS Description Document was used as the basis to analyze system requirements. This document also defined how system operation and integration functions are allocated to each element. Continued application of SE activities are necessary to ensure that overall system performance is maintained, that interface issues are resolved as they arise, and that optimal use is made of technology as it develops.

5.1.2 Engineering Support

Strategic Defense Initiative Organization (SDIO) engineering support involves five activities: (1) developing and publishing representative system threats; (2) coordinating system-level survivability efforts; (3) coordinating SDS element, system facility acquisition, and environmental compliance activities; (4) identifying integrated logistics support requirements; and (5) developing a system safety program.

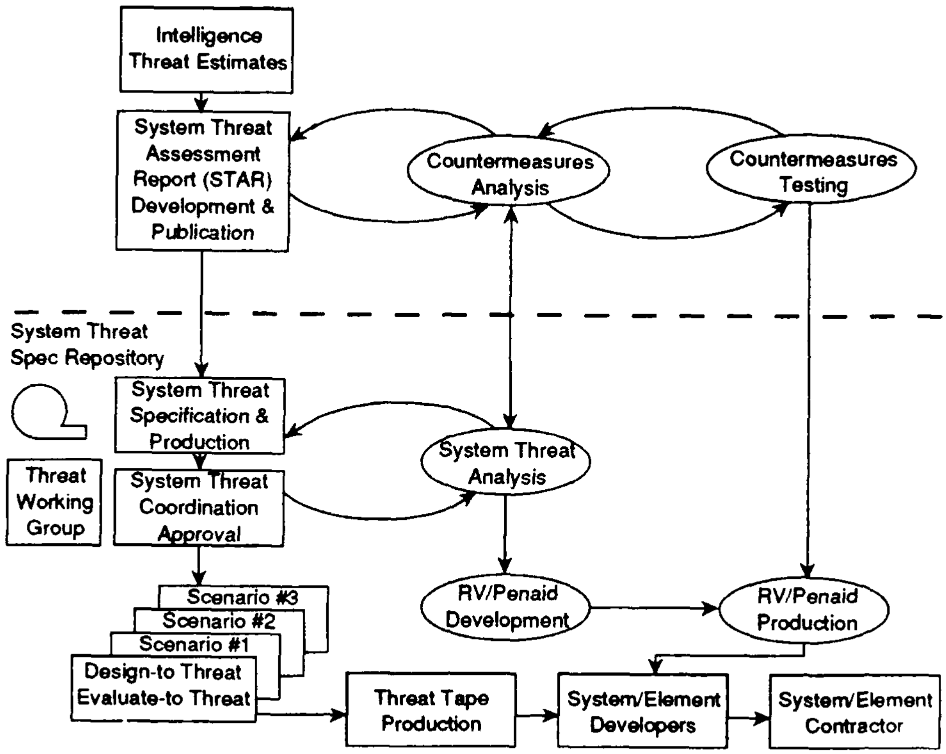
Threat

Identifying and prioritizing the most likely threats for the Phase I SDS and potential future architectures are controversial and difficult. Nevertheless, a major challenge in this area has been met. The SDIO, in cooperation with the Services, national laboratories, the intelligence community, and members of the SDIO-led Threat Working Group (TWG), has formalized a process to analyze the threat and threat excursions (Figure 5-1). The process was used successfully for the first time in reaching consensus on the SDS design-to threat which became effective in January 1990 and formed a basis for the SDS design process. The next major challenge will be to develop a complementing process to analyze threats that are excursions to the design-to threat. To support SDS threat analyses, the Special Program Center (SPC) has been established at the National Test Facility. The SPC is responsible for the generation, distribution, and archiving of threat tapes and maintains a centralized database of technical information to support threat modeling.

System-Level Survivability

Outstanding work is being done in analyzing the survivability of individual elements. To coordinate and integrate overall system-level survivability efforts, SDIO is developing a System Survivability Master Plan to identify system-level survivability criteria and milestones for accomplishing independent assessments of element and system performance under various robust system stresses. When completed, this plan will provide an enhanced understanding of potential design trade-offs and system performance; thus, it is also an integral part of the Test and Evaluation Master Plan.

Figure 5-1
Threat Analysis Process



Civil and Environmental Engineering

Real property facility acquisition and management are a vital part of SDS planning. Between 1985 and 1992, SDIO will have provided stewardship for over $2 billion of public funds targeted for SDS military or research and development construction. Just as crucial are the environmental analyses (EAs) that are being conducted to support various Dem/Val studies, such as the National Test Facility, GBR and GSTS activities at the Army's Kwajalein Atoll facility, and other ground-based interceptor activities. SDIO is committed to ensuring that no significant impact to the environment occurs at these sites as a result of SDI testing. EAs are also in progress for alternative space-based elements. The overall EA process is a continuing activity that is integrated into every SDS acquisition phase.

Integrated Logistics Support

The task of combining individual SDS element logistics concepts, principles, and capabilities into an integrated, cohesive effort is an essential part of the SDIO mission. SDIO delegates responsibility for element logistics to the Military Services while maintaining overall integration and standardization oversight. SDIO provides overall supportability policies and resources to develop generic support tools, models, and logistics technology to assist and coordinate element efforts. SDIO policies require early and continual logistics input and involvement of logistics considerations into the design process. This early infusion of logistics input is critical in estimating life-cycle costs, determining system reliability, and comparing potential performance of alternative design options. Other integrated logistics support activities include allocating reliability, maintainability, and availability goals to elements; refining and

using logistics models where learned data can be fed back into design, trade studies, and cost estimates; developing measurement standards for unique SDS applications; and evaluating the applicability of on-orbit maintenance concepts based on quantities and survivability aspects of current and future SDS elements.

System Safety

SDIO managers and the Services have safety activities that cover their individual efforts. SDIO will integrate these efforts and ensure that "lessons learned" are shared and that generic challenges are worked cooperatively. SDIO and the systems engineering and integration contractor are developing a system safety program tailored to the unique requirements of the SDS.

5.1.3 Producibility, Manufacturing, and Industrial Base

The objectives of SDI's ongoing producibility and manufacturing (P&M) effort are to ensure a producible and affordable SDS design and to ensure adequate industrial capability to produce the SDS when required. SDIO will achieve these objectives by developing and implementing a comprehensive SDS manufacturing strategy and supporting strategies by the Services' SDS element program offices. The strategies will be supported by detailed manufacturing plans, developed by the prime contractors and subcontractors in full-scale development (FSD), that follow the structure and issues of the Dem/Val strategy.

Manufacturing Strategy

The SDIO Manufacturing Strategy, published in August 1989, involves identifying, quantifying, and mitigating current and projected P&M risks, and developing and fully integrating new process technologies with long-lead development times across the SDS industrial base. The keys to the success of the strategy are to identify issues early, use a concurrent engineering approach to integrate product and process technologies, and initiate projects during Dem/Val to demonstrate solutions to issues by FSD. The Services' SDS element program offices are now developing supporting strategies.

A joint Service and SDIO P&M Working Group is prioritizing SDS P&M issues and is concentrating mitigation efforts on those issues with a higher risk. Current issues in work include developing manufacturing methods to produce radiation-hardened optics, resolving sources of scarce raw materials, improving production yield and unit cost, resolving testing shortfalls associated with sensor focal plane arrays, and addressing manufacturing process control and lead-time issues for radiation-hardened microprocessors. Critical P&M issues are being identified and examined during Dem/Val as part of the design trade-offs.

Manufacturing Operations Development and Integration Laboratories

The SDIO concept of Manufacturing Operations Development and Integration Laboratories (MODILs) represents a new approach to mitigating P&M risks. MODILs provide the transition between the laboratory and the production environment. These laboratories involve the collaboration of private industry, universities, and federal laboratories to develop and introduce emerging and enabling technologies into the industrial base. The overall goal is to provide the manufacturing capability needed to produce the SDS and achieve system quality and life-cycle cost goals.

Current MODIL activities include the Survivable Optics MODIL at Oak Ridge National Laboratory and initial projects directed toward establishing an Advanced

Infrared Sensors MODIL at Sandia National Laboratory. The Optics MODIL, initiated in FY 1988, addresses cost drivers and manufacturing technology to improve the producibility and affordability of optical components, shorten production lead times, and inject these needed manufacturing technologies into U.S. optical contractors. The newer sensors effort was initiated in FY 1989 to accelerate the development and transition of high-payoff focal plane array materials and technologies (alternatives to mercury cadmium telluride) into qualified, producible, and affordable components. Additional MODILs for signal processing and materials and structures are now under consideration. MODILs are simulating an SDS production environment, to the extent possible, using existing national resources and expertise so that P&M and cost issues can be attacked during Dem/Val.

5.2 Sensors, Command Center, and System Operation and Integration Functions

Sensors provide several key functions necessary for an effective SDS. These include surveillance (including tactical warning/attack assessment), target acquisition and tracking, and discrimination of target objects from decoys. In addition, the sensor functions must support the data requirements necessary for the command center, which will provide the overall battle management and control functions of the SDS.

This section provides an overview of the concepts and projects and the key technologies required for sensors (such as BSTS, midcourse sensors, and GBR) and CC/SOIF.

5.2.1 Boost Surveillance and Tracking System

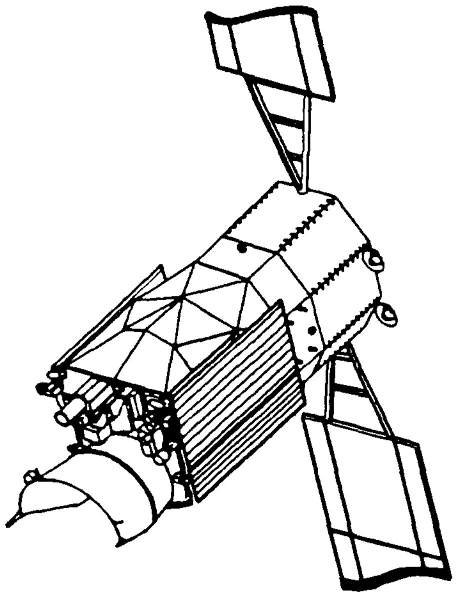
The BSTS is a missile launch warning system that detects launches, identifies boosters, and predicts the booster track of intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) during their powered flight. Deployed in a high earth orbit for optimum viewing and survivability, the BSTS uses advanced sensors and processing techniques to detect and track missiles by observing the missiles' hot exhaust plumes. Advanced on-board data processing capabilities determine missile position and velocity.

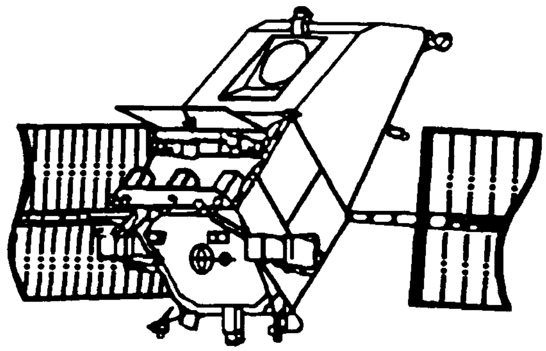
As a result of the requirement to maintain this nation's early-warning capability and the applicability of sensor technologies in SDI to this essential mission, the BSTS project is scheduled to enter FSD in FY 1991. The first FSD vehicle will perform at least tactical warning/attack assessment and other non-antiballistic missile missions. The BSTS will be capable of satisfying missions such as detection and characterization of nuclear events.

The BSTS constellation has the primary responsibility to provide warning information during boost. The satellite performs on-board analysis. The results of this analysis are transmitted to ground entry points.

The BSTS is in Dem/Val with two prime contractors developing the competing concepts shown in Figure 5-2. A single contractor will be selected to proceed with FSD and initial constellation production. Key issues will be resolved during Dem/Val by individual technology demonstration and in an end-to-end ground demonstration. During FSD, remaining technical and operational issues will be addressed by continued ground demonstration and the launch of the first FSD vehicle.

Figure 5-2
Two Competing BSTS Concepts





Technology Understanding

Critical to the success of the BSTS mission are signal/data processing developments, focal plane arrays (FPAs), large optics technology, and background/target phenomenology. These are discussed below.

Large focal planes generate large data streams that must be processed in real time. Radiation-hardened Very High-Speed Integrated Circuits (VHSIC) with large throughput capacity will be needed for real-time signal and data processing. On-board data processing technology requires small, fault-tolerant, low-power, radiation-hardened computers. The Generic VHSIC Spaceborne Computer (GVSC) is the cornerstone radiation-hardened integrated circuit project. Initial results of GVSC fabrication show very high yields and speeds that exceed specifications. Algorithms that evaluate large threat numbers are in development.

BSTS uses infrared (IR) detectors assembled into FPAs to detect the radiation emitted by the missile engines. The number of detectors required for BSTS FPAs is an order of magnitude greater than that required for the current early warning system. The FPAs must be survivable in a radiation environment. Because of their sensitivity and inherent radiation hardness, mercury cadmium telluride (HgCdTe) FPAs are being considered. Pilot lines and laboratory fabrication experiments have identified and are currently addressing key issues in both fabrication and production. Producibility initiatives have demonstrated cost reductions of up to approximately three orders of magnitude.

While recent design progress has reduced component requirement levels, the producibility of lightweight, 1-meter-class, steep aspheric, high optical quality, radiation-hardened mirrors has not yet been demonstrated. Current projects include

development of both glass ceramic and beryllium (Be) mirror technologies. Silicon carbide is also being explored, but it is not a mature technology. Survivability requirements make Be a strong candidate material. To date, one Be mirror in this size class has been fabricated, but it does not yet meet the required optical specification. Although fabrication of glassy material has been demonstrated, survivable coatings require extensive development.

BSTS sensor design requires a knowledge of boost-layer phenomenology. This phenomenology has three principal components: (1) the signature of the thrusting boosters, (2) the characteristics of the natural IR background, and (3) the characteristics of the enhanced IR background created by nuclear detonations. An extensive library of data exists for a single IR spectral region; however, the BSTS will be operating in multiple portions of the IR spectrum and at sensitivities beyond this database. Planned target signature and background experiments are critical for sensor design, calibration, and algorithm development.

Experiment and measurement projects supporting the BSTS include the Visible Ultraviolet Experiment (VUE) and Shuttle payload missions, such as Starlab, Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS), and the Infrared Background Signature Survey. The VUE and the related Three Color Experiment will augment a portion of the database required to validate high altitude system concepts. These experiments will augment a portion of the data necessary to measure plume signatures and backgrounds over extended wavelength regimes.

5.2.2 Miacourse Sensors

Detection, tracking, discrimination, designation, and handover of targets in midcourse are accomplished by a suite of cooperative sensors. Sensor concepts for the midcourse layer consist of the GSTS, SSTS, and the GBR. The GBR is discussed in detail in Section 5.2.3.

The midcourse sensors (MCS)—GSTS and SSTS—work together to track offensive ballistic missiles, post-boost vehicles (PBVs), reentry vehicles (RVs), and penetration aids. Target data from the MCS are transmitted to the Command Center Element.

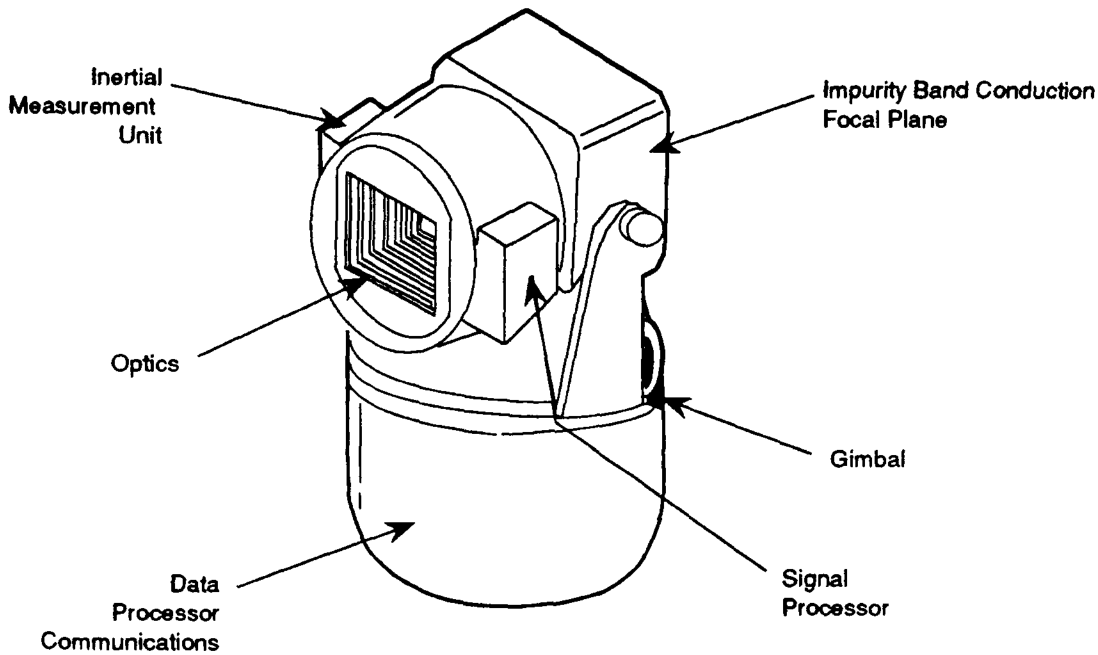
GSTS

The GSTS (see Figure 5-3) is a required MCS element with primary missions of midcourse precommit and early attack characterizations. In the midcourse precommit role, GSTS provides resolution of objects, object tracks, and passive discrimination with sufficient quality to support interceptor engagement. In the attack characterization role, GSTS provides regional surveillance of the threat attack for status and situational assessment. The GSTS is an integrated part of the midcourse sensor suite that also includes SSTS and GBR. GSTS also reduces the high traffic-density impact on GBR performance.

The GSTS is a ground-based, fast-response, two-stage, rocket-launched, long-wavelength infrared (LWIR) sensor boosted into suborbital flight for use in the midcourse layer. GSTS, when launched in pairs or singly for correlation with an SSTS, utilizes multiple line-of-sight correlated viewing to produce three-dimensional, high-resolution tracking and discrimination of the threat.

The GSTS sensor will be operationally integrated with SSTS and GBR to provide track and discrimination data. The GSTS searches selected corridors, flying close to the threat trajectories, to resolve closely spaced objects and to discriminate RVs from

Figure 5-3
GSTS Payload



penetration aids. Sensor data are then processed by ground-based processors. GSTS will also be used to cue GBR.

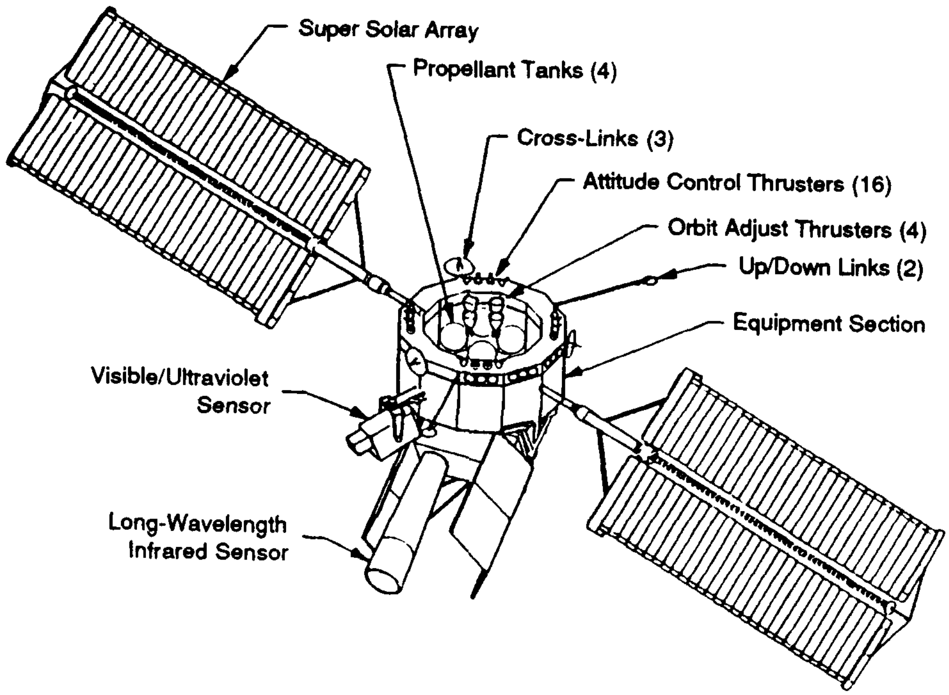
To provide an evolutionary design path to the Phase I SDS GSTS design and to support FSD, the GSTS acquisition strategy has been modified to include a total of three flight-qualified payloads and three flight-test missions in Dem/Val. The first two missions will conduct mono-passive flight tests, while the third mission will demonstrate stereo-passive correlated coverage.

SSTS

The Phase I SSTS (see Figure 5-4) consists of a constellation of satellites in polar orbits at medium altitude earth orbit . The satellites are supported by fixed and mobile ground stations which link the SSTS satellites with the ground segment of the SDS. The primary payloads on the satellites are two separate passive sensors used to measure target brightness and position to support the tracking and discrimination functions of the SDS. The first sensor is an LWIR sensor that is sensitive to the hard bodies rather than the rocket plumes of the objects to be tracked. The object signatures detected by this sensor are essentially functions of the objects' temperatures, sizes, and surface characteristics. The second sensor is a visible/ultraviolet sensor that is sensitive to the sunlit objects and possibly the plumes emitted by the boosters and PBVs during thrust modes.

The SSTS supports both wartime and peacetime missions. The primary ballistic missile defense missions include acquisition and tracking of PBVs and midcourse clusters (RVs, decoys, and debris) and ASATs in the post-boost and midcourse layers.

Figure 5-4
SSTS Concept



Accurate and timely tracking information will also support the integrated tactical warning and attack assessment functions to support the Command Center's battle planning. During peacetime, the primary responsibility of the SSTS will be to provide space surveillance of resident space objects and new foreign launches. Also, the collection of scientific and technical data on backgrounds will provide the necessary data for design optimization and computer code validation for future surveillance and seeker subsystems.

An SSTS Validation Satellite (SVS) will serve as the SSTS Dem/Val experiment to provide an evolutionary design path to the Phase I SSTS design. The System Requirements Review is scheduled for mid FY 1992, the System Design Review for mid FY 1994, and the Preliminary Design Review for early FY 1996. The first SVS is to fly in FY 1995/96 and will provide the needed proof-of-concept demonstrations while collecting the necessary data to support the Phase I design. The SVS sensor will be ground tested. The option to fly more than one SVS could support the space surveillance missions to a limited degree while demonstrating even more advanced technologies evolving into the Phase I SSTS. The Phase I SSTS is scheduled for transition to FSD in FY 1996, with Critical Design Review in FY 1998.

Technology Understanding

The principal MCS technical risks to be resolved include sensor optics, FPAs, on-board signal and data processing, and cryogenic coolers (SSTS only). Other issues include phenomenology (targets and backgrounds), discrimination of RVs from debris, and integration. Manufacturing and producibility issues are significant aspects of the signal and data processors, cryocoolers, large optics, and FPAs.

Like BSTS, current SSTS projects are focusing on silicon carbide and Be mirror technologies. Due to its natural resistance to radiation damage, beryllium is a strong candidate material to satisfy survivability requirements. This same survivability requirement drives the development of survivable coatings for the silicon carbide mirrors, which require extensive development. To date, Be mirrors of near adequate size and quality have been fabricated, but development is still required to make the mirrors affordable and producible.

Both SSTS and GSTS require large IR FPAs that stress producibility and performance issues such as noise, speed, power dissipation, radiation hardness, and detector size. The current designs focus on doped silicon impurity band conductors. SDI Program technology development has progressed substantially to meet the requirements of both SSTS and GSTS.

The signal and data processors for the MCS will build on the BSTS signal and data processor developments. The more stressing target scenario and natural and nuclear environments require that algorithm performances, processor throughput, fault tolerance, software complexity, and radiation hardening be addressed.

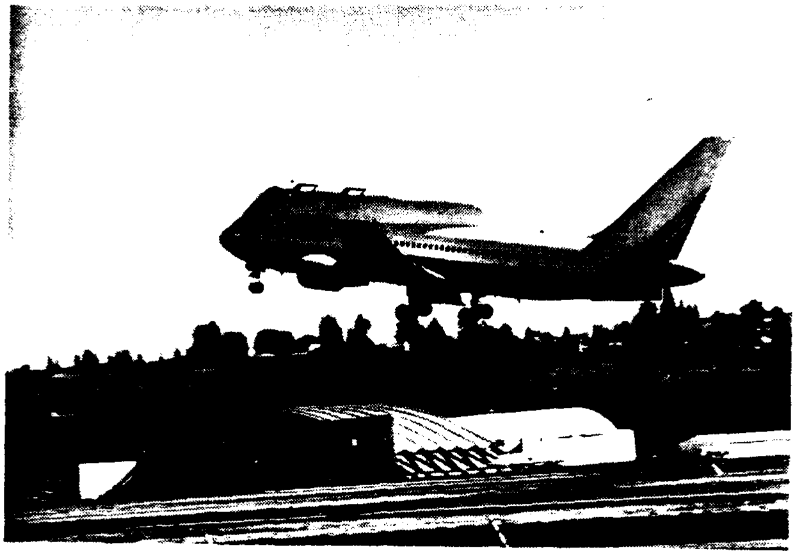
The midcourse sensor designs require a detailed knowledge of the midcourse phenomenology. This phenomenology is composed of three principal components: (1) the signature of the post-boost and midcourse objects, (2) the characterization of the natural background, and (3) the characteristics of the enhanced IR background created by nuclear detonations. Presently, insufficient data exist in the necessary wavebands of interest of the two elements. Several experiment and measurement projects supporting both SSTS and GSTS are planned and under way, including the Sounding Rocket Measurement Program, Midcourse Space Experiment, Exoatmospheric Discrimination Experiment, and Airborne Surveillance Testbed (discussed below). These experiments will provide a portion of the data necessary for target and background measurements over the necessary wavebands to support concept designs and validate computer simulations supporting the system designs.

The Airborne Surveillance Testbed (AST) has two major goals: (1) validate airborne LWIR surveillance sensor functional performance, and (2) provide a test bed for advanced surveillance technology. The major functions to be validated are long-range acquisition, discrimination, and high-accuracy track and handover to a ground-based sensor. The technology advancements to be tested include LWIR sensor components, real-time on-board signal and data processing, target signature measurements, and aero-optic effects and controls. The AST is shown in Figure 5-5.

The LWIR sensor, a scanning sensor of the same type to be used in SSTS and GSTS, was delivered in August 1988 for use as a major SDI test bed. Specifically, the test bed provides a signal processing capability of approximately 20 times that of the current Airborne Warning and Control System. This capability allows the finding and processing of thousands of targets. This test bed demonstrates the technical feasibility of a complex, wide-field-of-view LWIR sensor and will demonstrate tracking and discrimination functions against large numbers of midcourse targets. It also establishes confidence in the operation of later LWIR sensors at a greatly reduced cost and provides the ability to continue testing from an airborne platform.

The development of the critical algorithms necessary to utilize the data gathered by the sensors and reduce them into usable track data is being addressed by numerous programs in and outside of the MCS projects. End-to-end hardware and software experiments are planned in the future to demonstrate the capability of the algorithms to function in the environment anticipated for the sensors. These experiments are

Figure 5-5
Airborne Surveillance Testbed



designed to provide the supporting proof-of-concept demonstrations to support system designs and deployment decisions in the future.

5.2.3 Ground-Based Radar

The GBR will provide a late midcourse and high endoatmospheric active sensor to track and discriminate surviving reentry objects. Based on recommendations of the the Midcourse Sensor Study, the GBR became a candidate for inclusion as a Phase I element.

The GBR performs acquisition, track, discrimination, and kill assessment functions. In addition, the GBR will accept target handover from other sensors and provide track and homing data for ground- and space-based interceptors. The GBR is a single-faced, x-band phased-array radar. It provides enhanced discrimination by measuring the microdynamics of spaceborne objects. The GBR's search corridor is based on the evaluation of data provided by other SDS elements. The GBR can also operate in an autonomous target acquisition mode.

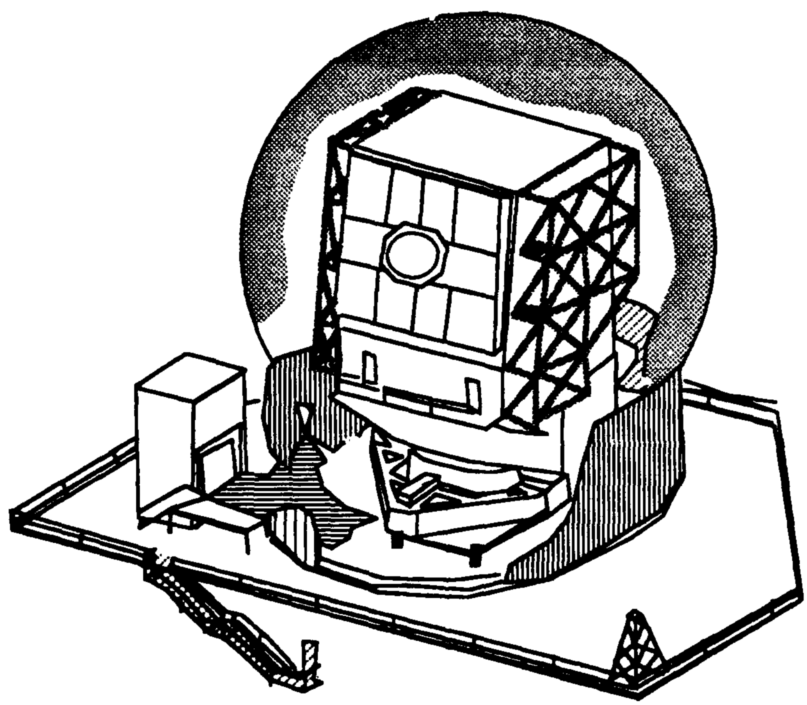
The two basing concepts under consideration are fixed site and rail mobile. Because rail mobility offers a potentially higher level of survivability, it is the GBR baseline approach. To meet mission requirements, a number of mobile radars and their associated support cars could be deployed across the northern CONUS border. The support cars would allow the crew to operate independently of outside support for weeks at a time.

A requirements definition study is being conducted during FY 1990-91. The project will perform threat/radar response evaluation and analyses leading to the preliminary system design process. Concepts will be evaluated in sufficient detail to establish effectiveness, technical and programmatic risks, cost estimates, and interface requirements. Following the study, two GBR contractors will then be selected for a competitive 12-month preliminary design effort.

Initial System

Prior to January 1988, the radar's design goal, as defined by the Terminal Imaging Radar (TIR) project, was to support the terminal phase only. The change to support the midcourse phase was accomplished by revising the technical requirements and issuing a change order to the TIR contract to start the GBR Experiment (GBR-X). The GBR-X, shown in Figure 5-6, will be used to demonstrate GBR technology in FY 1993-94. As a result of this approach, the GBR development cycle will be significantly reduced in cost and compressed in schedule as compared with a new start through significant technology transfer.

Figure 5-6
GBR-X



Technology Understanding

Three measures of radar performance are tracking accuracy, signal processing speed, and real-time imaging capability. The capacity for multiple target discrimination is limited by processor speed, design, and throughput. Traffic handling presents the major processing issue. Real-time imaging with an x-band phased array is a key technical capability. The GBR-X will provide estimates of handover volume, validate signal processor requirements, and provide the first data on real-time wide bandwidth imaging.

The GBR will provide a valuable capability for late midcourse discrimination. The foremost need for a GBR is the discrimination of advanced penetration aids. Discrimination is being approached through target motion studies and data analysis for the development of new discrimination techniques. The GBR-X will help to resolve discrimination issues and guide the development of effective new algorithms.

Radars must also identify RVs from a large and varied set of targets and masking devices. Over the years, a great deal of phenomenology has been collected to support radar design, largely in the terminal phase of the ballistic missile trajectory. However, the SDI Program has emphasized operations at higher altitudes—intercepting targets higher in the atmosphere and in space. This has placed new emphasis on collecting background and target signatures to support radar design and development. These data will be used along with simulated nuclear environments to test GBR algorithms for operational performance in nuclear environments.

Finally, the GBR must be capable of defeating a wide variety of electronic countermeasure techniques, including chaff and jamming. To accomplish this, programs to develop and test counter-countermeasure concepts are being initiated.

The technical issues concerning how the GBR will meet SDS mission requirements are radar performance, discrimination capability against advanced penetration aid suites, operations in the presence of electronic jammers and chaff, and operations in nuclear burst environments. The radar technologies involved in the GBR are extrapolated from state-of-the-art experience in other large radars and scaled upward for the higher frequency, increased power, and resolution requirements. Producibility issues must be resolved for the large numbers of phase shifters and power amplifiers required. Discrimination and operations in electronic and nuclear environments involve complex algorithm development and advanced signal processing and radar waveform generators.

Technical issues will be resolved during Dem/Val of the GBR. The GBR-X Functional Technology Validation (FTV), the keystone of the Dem/Val, will demonstrate the radar performance and discrimination capabilities in live testing at Kwajalein Atoll. Simulations on the National Test Bed will be used to prove GBR operations in electronic and nuclear environments. The GBR Requirements Definition Study, addressing such issues as basing mode and related support, will provide the requirements for two contractors to prepare a preliminary GBR design. The GBR FSD (Milestone II) decision is anticipated in FY1994 and will be based on radar and discrimination test performance. Difficult-to-test issues (e.g., operations in electronic and nuclear environments) will be demonstrated using high-fidelity simulation to resolve technical issues. The GBR-X FTV will also demonstrate phase shifter and traveling wave tube power amplifier producibility. The GBR-X FTV is in parallel with systems-level simulation development and the GBR Requirements Definition Study, all of which will be completed during FY 1990-94, supporting a Milestone II decision for FSD.

The current GBR project has the following other milestones: start GBR requirements definition (early 1990) and high-fidelity simulation (1990); GBR-X fabrication and CONUS tests, start deployable GBR competitive design, and ship GBR-X to Kwajalein Atoll (1992); conduct GBR-X FTV at Kwajalein Atoll (1993); complete deployable GBR design (1995); and demonstrate deployable GBR (1997).

5.2.4 Command Center/System Operation and Integration Functions

In 1990, the primary research focus of CC/SOIF development will be on human-in-control functions. An engineering model, the Pilot Command Center (PCC), is projected to be built and used progressively in FY 1990-94 to improve and refine the CC/SOIF. As a research and development model of the SDS Command Center element, the PCC will be used to test and prove the validity of command and control (C^2) concepts, resolve critical issues, and establish performance thresholds. The initial PCC, Build 0 (FY 1990), conducts experiments to validate C^2 requirements with

primary focus on human-in-control. Subsequent PCC development, e.g., Build 1 (FY 1991) and Build 2 (FY 1992), will conduct sensor management and integrated systems control experiments, respectively. In the Build 0 version of the PCC, a series of human-in-control decisions are being studied, including decisions relevant to events and attack confirmation, attack assessment, course-of-action selection, sensor and weapon control, and allocation strategies.

In accordance with a draft Memorandum of Agreement among the SDIO, the U.S. Army Strategic Defense Command (USASDC), and the U.S. Air Force (USAF), the acquisition responsibilities for the SDS Command Center Element (CCE) and the PCC experimental activities have been defined and assigned. USASDC and USAF will provide acquisition program management and lead acquisition agents for nonduplicated CCE subsystems and segments. SDIO will lead and integrate overall CCE acquisition and provide key management to include guidance, policies, and allocation of funding. SDIO will also provide the Common Test Environment (CTE) for the Services' C^2 elements. The CTE will be developed and hosted at the National Test Facility, the hub of the National Test Bed.

Technology Understanding

The critical CC/SOIF technologies previously identified continue to dominate research and development this year: algorithm development, software engineering, computer processor performance, communications, and networking. Critical design technology now in development includes the CCE and PCC projects.

The CCE includes four major functional areas and subsystems of SDS: (1) terrestrial capabilities and facilities for command and control, (2) the terrestrial communications network, (3) interfaces with entities external to the SDS, and (4) SOIF. All human-in-control functions are part of terrestrial capabilities and facilities for command and control.

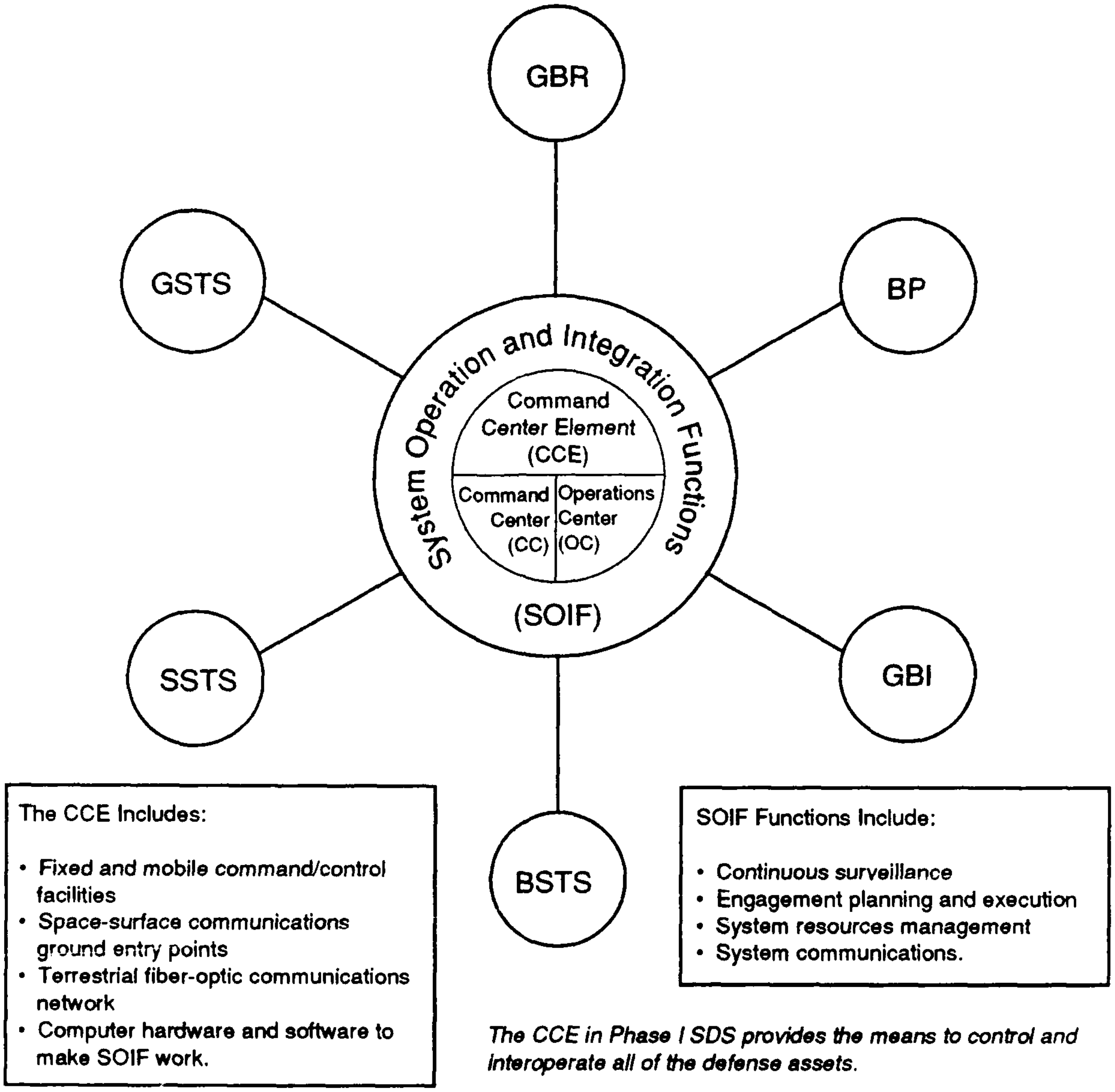
In the PCC project, the SDS command and control structure is represented by two overall function categories: the Command Center (CC) and the Operations Center (OC). The CC includes the ballistic missile defense cell of the consolidated Command Center and the Military Service components' command centers, which include mobile units. The OC group includes the Regional Operations Centers, some of which also are mobile.

This distributed arrangement of SDS command and control and its interconnecting communications network significantly contribute to a reliable and survivable SDS. Figure 5-7 illustrates the role of CC/SOIF and its relationship to the major sensors and other elements of the Phase I SDS. The CCE should be ready for FSD by FY 1995.

5.3 Initial Kinetic Energy Projects

Initial interceptor projects are the BP and GBI. These projects provide the basic interceptor elements of a flexible layered defense. BPs are designed primarily to intercept and destroy boosters and PBVs. The GBI will destroy RVs in the midcourse layer. This combination of space- and ground-based interceptors can be changed to respond to the evolving threat characteristics and attack strategies.

Figure 5-7
Command Center Element in a Phase I SDS



The CCE in Phase I SDS provides the means to control and interoperate all of the defense assets.

The following paragraphs describe the autonomous BP interceptor and the SBI backup. A description of advances in GBI development follows the discussion of the space-based elements.

5.3.1 Brilliant Pebbles

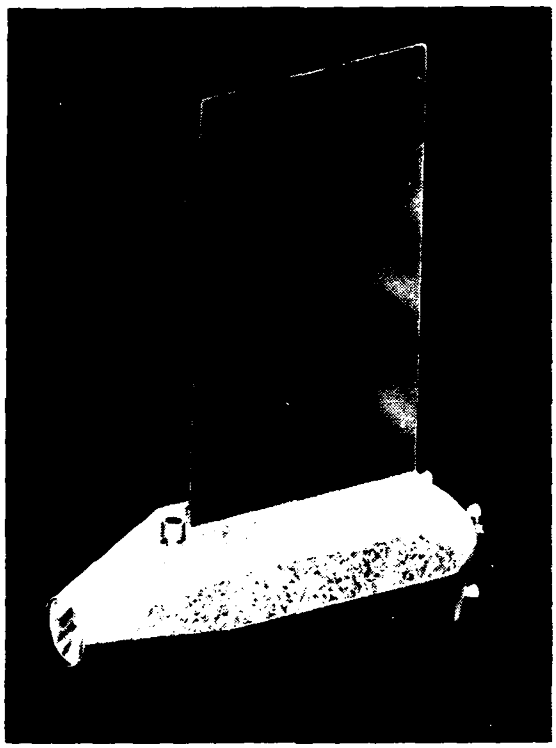
In the 1989 Report to the Congress on the SDI, BP was described as an innovative approach to performing the defensive functions in the boost/post-boost layer that would be assigned to space-based kinetic energy interceptor. Since that time, the BP technology has matured, and many of the issues concerning feasibility have been addressed. The following paragraphs highlight the current BP technology, discuss

how it would operate in an SDS, and report results of an extensive series of BP reviews. Streamlined management of the project is also discussed.

Brilliant Pebbles Technology

The BP concept consists of singlet interceptors and their associated "life jackets." The interceptor consists of a lightweight, low-cost, single, hit-to-kill kinetic kill vehicle (KKV) that provides integrated sensors, guidance, control, battle management, and a drop-away propulsive stage. The conceptual interceptor design is shown in Figure 5-8. The interceptor has a velocity change capability which is continuously apportionable under computer control to either axial or transverse (divert) maneuvering.

Figure 5-8
Brilliant Pebbles Conceptual Interceptor Design



The life jacket houses a single interceptor and its survivability suite. The life jacket is being designed to survive an enhanced background indefinitely at the basing altitudes of the BP constellation. The life jacket functions to provide on-orbit power and energy storage, low-rate attitude control, IR sensor cooling, camera control, 60 gigaHertz communications, thermal control, and survivability. High-rate attitude control, data processing, navigation, and divert propulsion are provided by the interceptor. Upon commencing engagement of a target, the interceptor sheds the life jacket.

Brilliant Pebbles in Operation

The BP element of the SDS will be deployed in low earth orbit. Its interceptors will be used to destroy targets in the boost and post-boost portions of the targets'

trajectories by collision at multi-km/sec speeds. Several thousands of the singlet interceptors will be in the BP element. BP is the space-based kinetic energy interceptor element of a two-tiered SDS architecture and will operate in concert with a ground-based tier consisting of ground-based interceptors, sensors, and command and control capabilities. Supporting elements and quantities are consistent with Phase I.

The BP constellation will be supported by minimal ground-based equipment. Health and status monitoring will be handled by the Space Defense Control Center (SDCC). The SDCC will serve to control the basic functions of the BP constellation. Replacement interceptors will be launched as needed to maintain full BP element availability (including predeployed spares).

Reviews of Brilliant Pebbles

The summer of 1989 was a period of intense scrutiny of BP. Both the JASONs and the Defense Science Board spent considerable time reviewing the concept, the associated technology, and BP effectiveness as an SDS element. In each case BP was commended for its advances and innovative approach and received a recommendation to continue with the research.

In addition, Red-Blue countermeasure teams examined BP survivability and robustness to Soviet countermeasures. Teams of technical experts examined BP and other components for their soundness and feasibility. Finally, costing teams have verified the low costs of the BP. The composite reviews have thoroughly scrubbed the details with favorable results and support the recommendation to proceed with the project.

Streamlined Management

The BP project features a highly streamlined management and acquisition approach to bring industry on board while maintaining the simplicity and low-cost features of the original BP concept. The underlying motivation for such an approach is an outgrowth of the Packard Commission recommendations.

First of all, there is a greatly simplified management structure from the Secretary of Defense to the SDIO and National Laboratory Task Force to various contractors. Second, no formal military specifications or standards are being imposed on the project at this time. Rather, the contractors are being given maximum flexibility in their development activities. Third, short and simple requests for proposals and contracts, the latter with minimum reporting requirements, are being used. The overall intent of these innovations is to achieve a fast-paced yet simplified development project for BP.

Industry involvement in Brilliant Pebbles will be pursued beginning in FY 1990 through concept definition (CD). Primary emphasis will be on innovative design of an interceptor with excellent autonomous homing intercept performance, which is producible at low cost through high-volume manufacturing. The point of departure for the interceptor design will be the Lawrence Livermore National Laboratory BP concept. Risk reduction through backup technology will be encouraged. Interceptor life-cycle cost is a critical parameter which will be addressed in terms of production; acceptance, developmental, and operational testing; and deployment. The CD phase will have an 8-month period of performance. SDIO currently plans to conduct a pre-FSD phase of approximately 3 years immediately following the CD phase.

5.3.2 SBI Backup to Brilliant Pebbles

The SBI backup to BP is a chemically powered, space-based kinetic energy interceptor. What has happened in the last year, as highlighted by the BP discussion, is a major advance in our perception of space interceptor performance and accompanying decreases in cost, weight, and size. As a result of further study, the operation of each interceptor (the basic BP concept) can now be projected with considerable confidence. Nevertheless, because of the importance of boost-layer intercepts, it is prudent to continue pursuing SBI development for the technology spin-offs that will help BP. For example, in one approach, the brassboard designs of the inertial measurement unit (IMU), navigation and control processor, divert propulsion, and kill vehicle structure will be completed in FY 1990 and integrated with the seeker for a hover test in FY 1991. This hover test vehicle will be refurbished to be available to piggyback on SDIO ballistic flights to demonstrate a four-color passively guided interceptor concept. In an alternate approach to technology development, the divert propulsion and KKV structure will be integrated for a hot-fire test in mid 1990. In 1991, the brassboard IMU, nuclear-hardened guidance and control processor, and visible camera will be added to the test vehicle for the integrated hover test. A hardware-in-the-loop demonstration of the IMU, processor, and seeker is also planned in FY 1991 to demonstrate a two-color integration. These tests provide a broad-based foundation of technologies for interceptors applicable to several SDI programs and as a backup to BP.

5.3.3 Ground-Based (Exoatmospheric) Interceptor

The Ground-Based (Exoatmospheric) Interceptor element of the Phase I SDS is a kinetic energy interceptor. The GBI's mission is to intercept and destroy hostile RVs in the midcourse portion of their trajectories. These ground-based non-nuclear interceptors would be launched from fixed sites in the CONUS using target information acquired by the MCS elements and discriminated and handed over by the ground-based CC. The GBI element design is being optimized to provide the greatest military effectiveness at the lowest SDS life-cycle cost.

Technology Understanding

The GBI project consists of three distinct efforts: Exoatmospheric Reentry Vehicle Interceptor Subsystem (ERIS) Functional Technology Validation (FTV), GBI Baseline Design and Engineering Development, and the Exoatmospheric Test Bed (XTB). During FSD approximately 22 GBI flight test vehicles with hardened components would be built and tested. Key components include the optical seeker, signal and data processor, divert and axial propulsion, and IMU. The primary goal is to maintain low weight while increasing processing throughput and electronics hardening, which will be accomplished using state-of-the-art VHSIC. Figure 5-9 compares the ERIS FTV with the operational GBI.

Through a series of flight tests in FY 1990-91, the ERIS FTV will provide a demonstration and validation of an interceptor built using mostly off-the-shelf technology. These missions will address a variety of critical issues, including target acquisition with a body-fixed LWIR scanning seeker, aimpoint selection on the RV, and target acquisition under stressing conditions using a target object map. The FTV kinetic kill vehicle is shown in Figure 5-10.

Figure 5-9
Comparison of ERIS FTV and Operational Ground-Based Interceptor

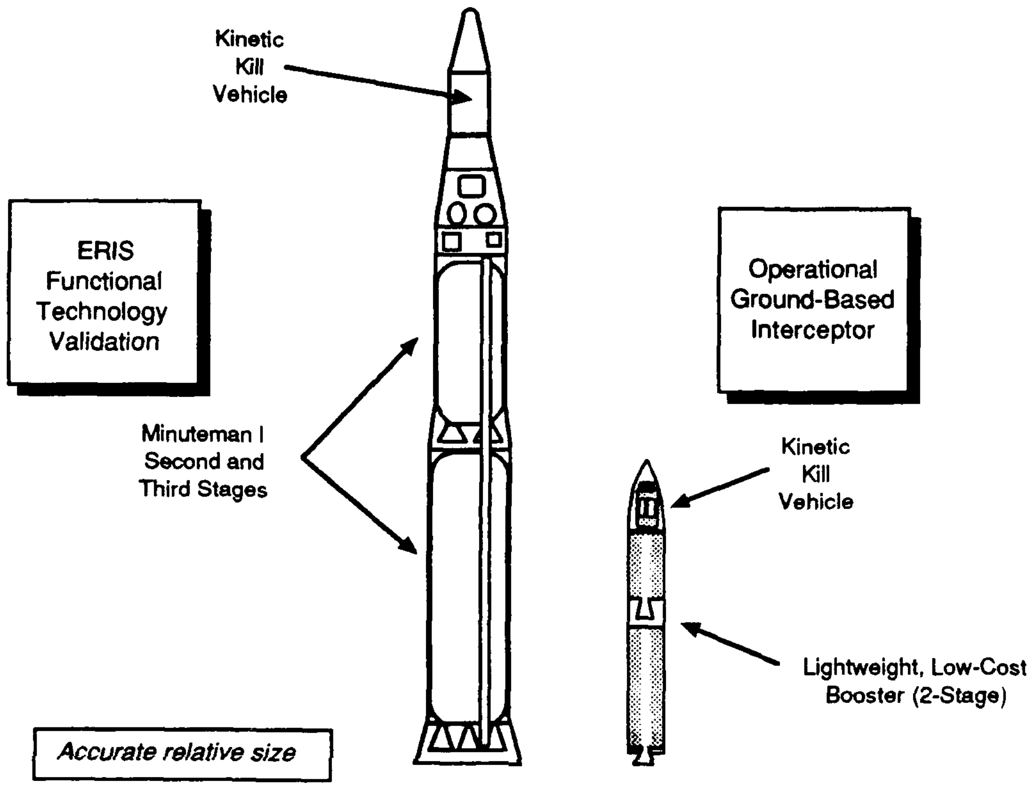
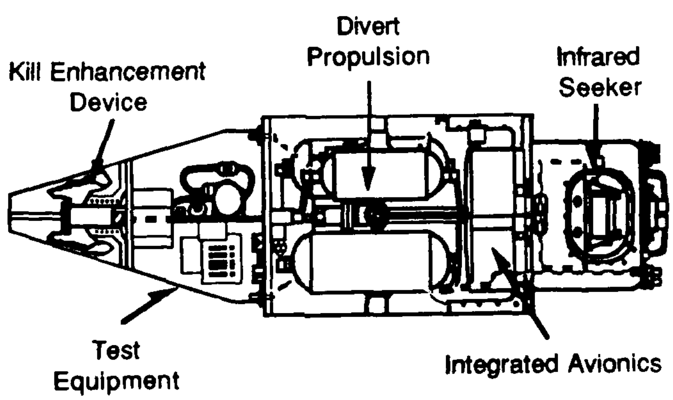


Figure 5-10
ERIS Functional Technology Validation Kinetic Kill Vehicle



The GBI baseline design and engineering development effort will competitively select two or more Dem/Val interceptor concepts that incorporate advanced technologies, including seekers, avionics, and divert propulsion, some of which were developed and tested under other SDIO element and technology projects. These concepts will be integrated into the GBI baseline design and will help develop a GBI specification. Technologies being examined include advanced seekers with cooled optics, advanced IMUs, visible and ultraviolet FPAs, and improved hardened avionics.

Initial System

The XTB will provide SDIO and the Army with the capability to launch experimental payloads from the U.S. Army Kwajalein Atoll for exoatmospheric tests and technology demonstrations. A goal of this effort is to ensure that a valuable experimental resource is preserved beyond the duration of the FTV effort and is made available to other Department of Defense agencies.

5.4 System Validation

The validation of the SDS is supported by two key components: test and evaluation (T&E) and the National Test Bed (NTB). The goal of the T&E activities is to demonstrate that the system is effective, survivable, and operationally suitable. The purpose of the NTB is to provide a comprehensive capability to compare, evaluate, and test alternative architectures; develop CC/SOIF; and provide the simulation for an SDS. These two components that validate the SDS are described in this section.

5.4.1 Test and Evaluation

The T&E goal for the SDS is to provide objective, timely information on potential SDS performance. This information will support future national decisions on the development and deployment of an SDS that meets the requirements and operational concept of the user.

Ultimately, SDS testing must resolve issues associated with system survivability and effectiveness over a range of conditions. The flow-down and translation of these issues into requirements on the elements provide a basis for identifying system-integrated testing that must occur during FSD. To comply with Section 141 of Title 10, U.S. Code, low-rate initial production quantities of test articles for FSD testing must be determined and major FSD test resource requirements must be identified before the SDS can proceed beyond Dem/Val. Requirements for proceeding beyond Dem/Val, in turn, are currently guiding identification and prioritization of testing that must be conducted during Dem/Val of Phase I elements.

Due to the complexity of the SDS, developmental and operational T&E will depend heavily on element, system, and operational simulation. Policies and procedures for SDI tests, experiments, and simulation are being established that emphasize requirements traceability; early system integration testing (beginning with non-real-time experiments of functional test vehicles); use of hardware-in-the-loop testing to validate simulations; use of simulations for test preparation; and testing at system critical design points. This framework will maximize common usage of testing and simulation results for independent evaluation by the responsible development and operational test organizations.

Commander-in-Chief, U.S. Space Command, has provided a set of Critical Operational Issues (COI) that shall form the basis for the operational T&E of the SDS. These COIs are:

- Mission performance. The SDS shall meet performance requirements as identified in the Joint Operational Requirements (JOR), against the Defense Intelligence Agency (DIA)-validated threat, using the tactics, doctrine, and procedures outlined in the U.S. Space Command Concept of Operations.

- Responsiveness to command and weapon system control. The SDS shall support timely and effective decision processes during peacetime operations and across the entire spectrum of warfare in response to valid direction and authority.

- Security of system components. The SDS shall have adequate security to prevent the penetration or exploitation of its mission-essential capabilities.

- Functional survivability. The SDS shall perform its mission to the degree specified in the JOR despite man-made hostile actions as described in the DIA-validated threat.

- Operational availability. The SDS shall be sufficiently reliable and maintainable to ensure that the system is available when called upon to perform its mission.

- Testability. The SDS design shall facilitate operational testing and the verification of operational readiness of the system to ensure mission requirements are met throughout the system life cycle.

- Interoperability/compatibility. The SDS shall be interoperable and compatible with friendly offensive and defensive forces and systems, and the SDS elements shall be interoperable and compatible with one another.

- Supportability. The logistics, manpower, and industrial supportability base shall be adequate for deployment and employment of the system.

Simulations for evaluation of SDS performance will take advantage of the capabilities of the NTB. Currently, four key system-level simulations are being developed on the NTB: the Pilot Command Center and the Communications Network Test Bed, which are real-time simulations, and the System Test Bed and the Integrated Surveillance Test Bed, which are non-real-time simulations. SDS T&E policies and procedures are being developed to ensure that tests, experiments, simulations, and documentation of results are verified and validated in a disciplined manner.

5.4.2 National Test Bed

The NTB is a sophisticated research laboratory designed to simulate, test, and evaluate strategic defense concepts, architectures, battle management, and hardware applications. Additionally, the NTB is testing command and control interface with human-in the-loop and hardware-in-the-loop technologies.

The NTB is a network of geographically dispersed test facilities, connecting nodes of the Army, Air Force, Navy, and national laboratories. The National Test Facility serves as the operational hub of this integrated system of satellite and ground-linked test facilities. The NTB's capabilities have been centralized to ensure that a single integrated capability dedicated to the SDS is available to the entire SDI community.

Decisions on feasibility, application, and ultimate deployment of SDS technologies must be based on careful tests and evaluations. The NTB will conduct this research using supercomputer-driven simulations. These simulations will assess not only the capabilities of newly developed hardware, but also how human decision makers are able to interact with highly sophisticated systems. The NTB hosts the following activities: computer simulations to aid in the design of and to validate SDS architectures and the planning and operation of hardware assets; exercising and verifying the CC/SOIF and doctrine associated with SDS and space defense operations;

development of a comprehensive database of simulations; operation of a software center incorporating software technology and development tools; operation of a software engineering environment, rehosting, and applications library; interactive gaming; conduct of studies and analysis of simulation results; and experiment planning, test, and evaluation.

Chapter 6

Follow-on Systems

Chapter 6
Follow-on Systems

Advanced concepts that could be applied to follow-on architectures are being examined as part of the SDI Program. This chapter addresses the advanced interceptors and directed energy concepts that are potential candidates for elements of follow-on systems.

6.1 Follow-on Kinetic Energy Concepts

This section describes the High Endoatmospheric Defense Interceptor (HEDI) and hypervelocity gun (HVG) projects.

6.1.1 High Endoatmospheric Defense Interceptor

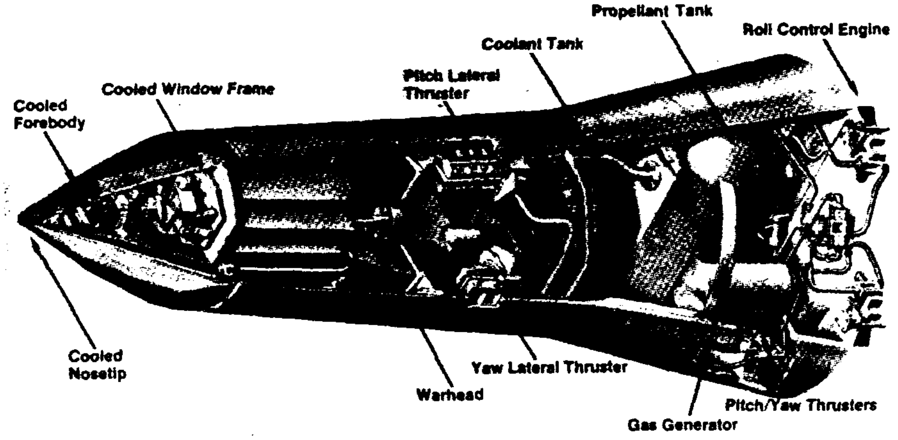
HEDI is a ground-based, hypervelocity, high-acceleration interceptor designed to destroy ballistic reentry vehicles (RVs) high in the atmosphere. The kill vehicle (KV) is protected by a shroud until just prior to acquisition of the target during the final seconds of flight. An infrared (IR) seeker is used to acquire, track, and home on the target. A laser rangefinder is used to provide range accuracy for fusing the non-nuclear warhead. HEDI is designed to be used in a fire-and-forget mode, but is also capable of using in-flight updates of target information. HEDI is normally committed to intercept a target when interaction with the atmosphere strips out all the light objects accompanying the target RV in its trajectory. Increasing the commit altitude (exoatmospheric commit) increases the area of the footprint that HEDI can defend. Likewise, using a dual-color seeker could increase the ceiling of HEDI's battlespace, denying the threat of a battlespace gap between the midcourse interceptor and HEDI.

The IR seeker allows HEDI to intercept high in the atmosphere. This battlespace enables HEDI to intercept intercontinental (ICBM) or submarine-launched ballistic missile (SLBM) RVs that penetrate the midcourse defense layer as well as RVs from depressed-trajectory and short-flight-time SLBMs that may underfly the midcourse interceptors. The unique aspect of this battlespace is that it requires the HEDI seeker to operate in a severe aerothermal and nuclear environment.

The HEDI configuration includes a two-stage rocket booster, which provides high acceleration and a high burnout velocity, and the KV along with its protective shroud. The KV (see Figure 6-1) consists of the IR seeker, a fragmentation warhead with laser fusing, a thruster control system for guidance maneuvers and attitude control, a cooled window for seeker viewing in the severe aerothermal environment, associated avionics, and the airframe.

The HEDI project is structured with three main phases: the Kinetic Energy Kill Vehicle Integrated Technology Experiment (KITE), the Experimental Test Vehicle (XTV), and full-scale development (FSD). The first two phases are specifically designed and required to resolve critical technical issues related to phenomenology associated with operation in the atmosphere and incorporating emerging technologies into the program. The KITE phase provides the basis for the XTV flight tests at Kwajalein Atoll, which lead to FSD of the operational HEDI.

Figure 6-1
HEDI Configuration



KITE is a test bed vehicle for the demonstration/validation (Dem/Val) phase of HEDI. The HEDI KITE program was initiated in January 1986 with direction to (1) use off-the-shelf hardware, wherever possible, and existing boosters for propulsion (surplus SPRINT motors); (2) develop the critical components and technology required to demonstrate the acquisition, homing, and non-nuclear kill of an RV in the high-endoatmosphere; (3) address critical issues for high-endoatmospheric defense; and (4) reduce program risk by a parallel development of selected critical components.

The present FSD plan for the HEDI project assumes that the XTV booster and possibly some KV hardware will be used in the initial FSD test phase, which could occur as early as the mid 1990s.

6.1.2 Hypervelocity Guns

The goal of the HVG project is to develop rapid-fire HVGs and compatible projectiles capable of supporting Strategic Defense System (SDS) missions in ground- and space-based roles. To accomplish the overall goal, an HVG must be developed that is capable of repeatedly launching flight-weight projectiles at acceptable velocities and efficiencies and has a reasonable barrel life. Supporting subsystems such as prime power, power conditioning, switching, and feeders must also be developed. Projectile development issues include highly sensitive seekers, divert propulsion, high-density electronics, and the ability to withstand the high-acceleration launch environment (100,000 times the force of gravity). Fire-control hardware/software must be developed to handle multiple projectiles against high numbers of targets. The HVG project also includes Strategic Defense Initiative Organization sponsored research and development efforts with selected allies. The Netherlands provides research into advanced pulsed power and switching, while the United Kingdom provides complementary efforts in areas of barrel, armatures, and power supplies.

Ground-based HVGs at fixed sites could be capable of intercepting strategic RVs at medium altitudes (that is, greater than 30 kilometers) and could also be utilized in an antitactical missile role. When combined with a "smart" projectile using seekers and aerodynamic maneuvering for terminal homing, the HVG element can be a highly

effective terminal phase adjunct to SDS. The terminal phase HVG could reach FSD as early as mid FY 1996. Space-based HVG platforms with 7- to 10-km/sec launch velocities would have the ability to intercept threats in the boost, post-boost, and midcourse stages of flight.

6.2 Follow-on Directed Energy Concepts

Directed energy devices possess unique characteristics such as speed-of-light delivery and long-range/multiple-shot capability that make them effective candidates for an evolving, threat-driven SDS. Because of these unique attributes, directed energy devices have the ability to perform all of the classic strategic defense roles, from threat detection to destruction. Primary applications are in booster and post-boost vehicle destruction and interactive discrimination of advanced decoys in the midcourse layer. In addition, the advanced surveillance capabilities of these devices will enable detection and tracking of the missile, post-boost vehicle, or deployed RVs, and handover and designation of targets for space-based interceptors. Directed energy devices are capable of evolutionary growth from early boost-phase intercept capability to the performance levels required to negate robust, long-term responsive threats.

The directed energy technology program discussed in this section brings together research addressing three basic concepts identified as promising approaches to meet the needs of a multitiered defense: ground-based laser (GBL), space-based laser (SBL), and neutral particle beam (NPB). In the phased approach to development, these concepts will be introduced into later SDS architectures as they reach technical maturity and as mission requirements change or the threat changes in response to the initial SDS. Directed energy concepts offer the promise of maintaining and/or improving system effectiveness even against a rapidly evolving threat.

Acquisition, tracking, pointing, and fire control efforts support these concepts and are discussed following the basic concept subsections. In addition, there is a continuing level of effort in element concept formulation that also supports all of the directed energy concepts. This ongoing effort is designed to identify the technology content of the concepts so as to guide technology development and provide conceptual designs for evaluation in potential SDS architectures.

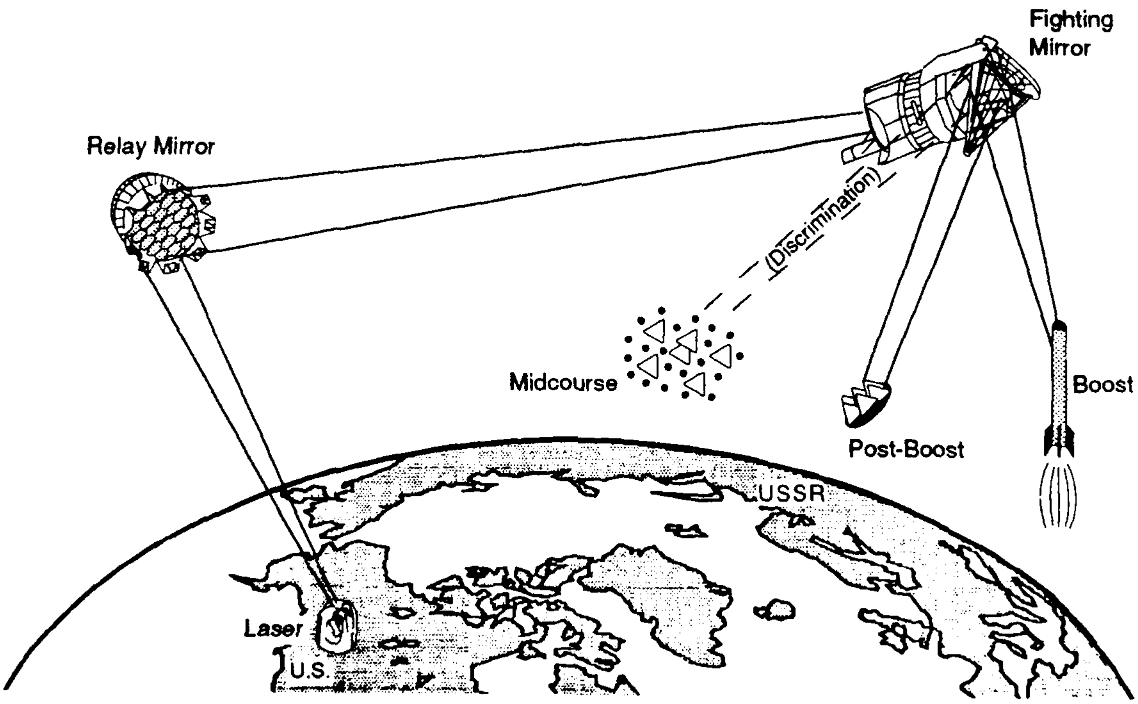
The SDI Program is focused primarily on non-nuclear technologies. However, to understand the potential impact of any such technology that the Soviet Union might develop as well as to determine the feasibility of these concepts for future U.S. SDI options, the Program is exploring the feasibility of nuclear-driven directed energy concepts. (See Chapter 7 for a discussion of this effort.)

The most viable long-term SDS architecture would employ multiple defensive layers of kinetic energy interceptors, lasers, and particle beam devices that could engage ballistic missiles throughout their trajectory. This triad-like SDS structure, with two legs of directed energy weapons (DEWs) and one leg of kinetic energy weapons (KEWs), would provide mutually reinforcing capabilities and positive synergism that would not be possible with a system consisting only of KEWs or DEWs.

6.2.1 Free Electron Laser/Ground-Based Laser

Development of the GBL element exploits the advantages of limiting the weight on orbit by retaining the beam generation function on the ground. The GBL employs laser devices based on the ground that generate an intense beam of near-visible radiation (see Figure 6-2). The high-energy laser beam is transmitted through the ground beam control subsystem, which corrects the beam for proper transmission through the atmos-

Figure 6-2
Ground-Based Laser Concept



phere to the relay mirror spacecraft. The beam is then redirected to the input telescope of the mission spacecraft and focused on the target by the mission spacecraft output telescope. The GBL concept is conceived as a device capable of evolutionary growth in boost-layer intercept, interactive discrimination in midcourse, and adjunct missions in antisatellite (ASAT) operations and surveillance.

The GBL project is structured to pursue a Milestone I decision in the mid-1990s timeframe. Based on the results of the subsequent Dem/Val phase for each candidate, a Milestone II decision to enter FSD could be made in the late 1990s. FSD will culminate in a prototype demonstration.

Technology Advancement

This description is focused on achievement of the project goals dealing with system-level experiments and tests (e.g., the Ground-Based Free Electron Laser Technology Integration Experiment [GBFEL TIE] and the space segment demonstrations). The overall project can be grouped into four concept-specific technical areas that must be pursued: device scaling; propagation and beam control; space optics and beam control; and acquisition, tracking, and pointing, a functional integration area shared with other DEW concepts.

The research consists of intensive laboratory and field work that will demonstrate the GBL technology needed to enter FSD. It is focused on five major objectives. First, the research will show that free electron lasers (FEL) can be built, integrated, and operated at multimegawatt power levels. Second, it will show that distortions of the laser beam caused by uneven heating of the atmosphere and other phenomena can be corrected and compensated on the ground using an adaptive optics subsystem. Third, the research will demonstrate that a very high-power laser beam can be steered by a beam director, acquire and track a space target board, and deposit its energy on that space target. Fourth, it will demonstrate the systems integration and operation of a FEL, a beam control subsystem, and an atmospheric compensation subsystem. Fifth, the research will demonstrate the feasibility of a space-based relay mirror integrated with ground elements to validate the GBL concept for strategic defenses.

To meet these objectives, the research is focused on three major activities. The first, GBFEL TIE, addresses the ground segment components of lasers, beam control, and adaptive optics. The second activity is concerned with the space segments, where relay and fighting mirror spacecraft will be designed and subscale hardware fabricated for a space experiment during the Dem/Val phase. The last major activity deals with risk reduction and supporting technology.

Essential functions of the GBL fighting mirror satellite will be demonstrated by a space-based experiment. A test of the laser and other components will be conducted in FY 1995. The beam control subsystem has been deferred until the laser has matured. The integrated up-link experiment will therefore be delayed until the FY 1996 timeframe. Once this up-link capability has been proven successful, a high-power laser relay experiment will be performed. Testing the GBFEL TIE with a space relay mirror will demonstrate all of the essential functions for a ground-based laser. A GBL with space based components will be available for realistic integrated tests with other SDS elements.

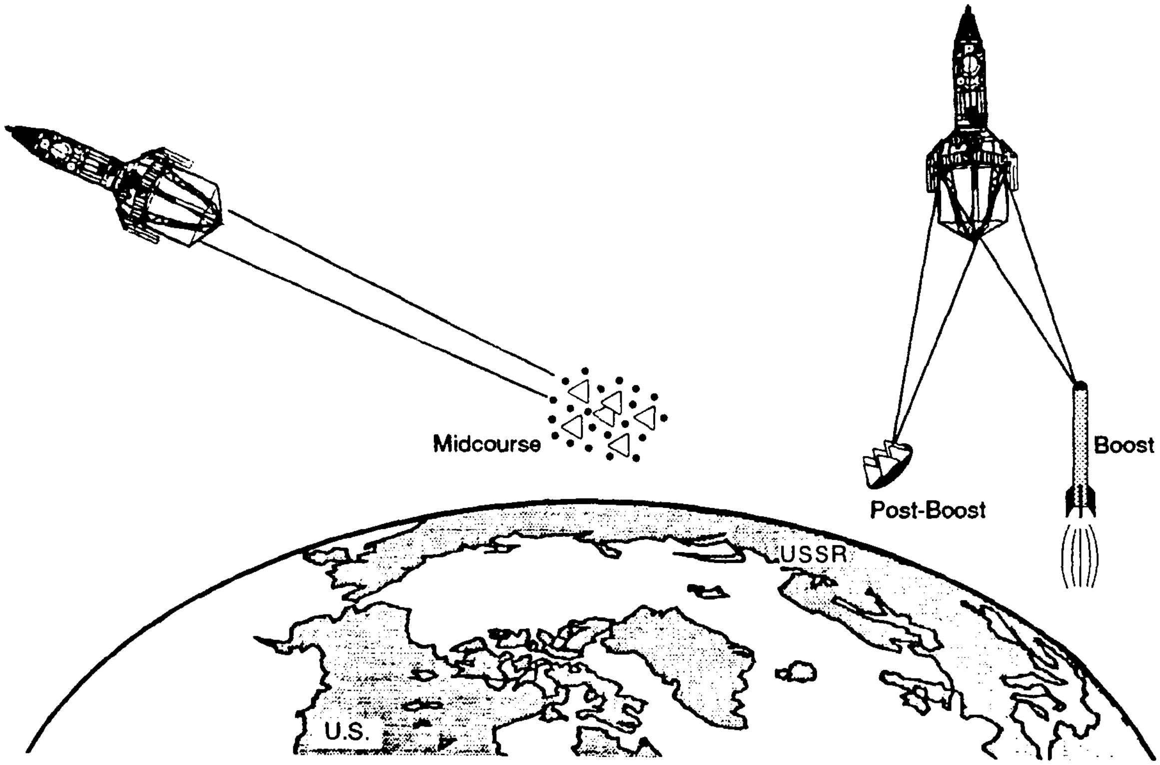
To date, an adequate preliminary design of the GBL concept has been completed, stabilizing the design approach. As a result, the design approved for the GBFEL TIE is structured to resolve the full range of technical issues related to transmitting lethal laser energy through the atmosphere. Similarly, the enabling technologies of the relay mirror have been developed to the point that the viability of this approach has been confirmed. Lastly, technical progress in large optics fabrication and test and beam control within the SBL project will ensure that the development risk for the fighting mirror is essentially engineering in nature.

6.2.2 Chemical Laser/Space-Based Laser

The development and deployment plan for the SBL element exploits the inherent simplicity of the hydrogen fluoride chemical laser and the economic and production benefits of modularity. The SBL consists of orbiting, highly autonomous, multimission battle stations (see Figure 6-3) capable of directing extremely powerful and agile IR laser beams onto targets of interest. These battle stations could destroy missiles in boost phase down to the cloud tops. They could also provide interactive discrimination by destroying simple decoys (e.g., balloons) and thermally tagging or imparting a velocity change to more sophisticated decoys.

The system building blocks (modules) to be orbited initially are single-aperture platforms. Their brightness, to be determined by the initial missions assigned to the SBL in a sequentially deployed architecture, is expected to be high. Technologies are being developed which enable platform growth to very high brightness levels, while

Figure 6-3
Space-Based Laser Concept



maintaining the benefits of modularity. This assures the capability for countering extremely stressing countermeasures in the far term.

The SBL project is structured toward a Milestone I decision in the early-1990s timeframe. Based on the results of the subsequent Dem/Val phase for each candidate, a Milestone II decision to enter FSD could be made in the late 1990s. FSD will culminate in a prototype demonstration.

Technology Advancement

This description focuses on achieving the goals for the entry level capability through system-level experiments and tests (e.g., Complementary Space Experiment and Zenith Star). The critical technical issues for the SBL element can be grouped into five areas: laser device; beam control; optics; acquisition, tracking, pointing, and fire control (ATP/FC); and high-power integration.

The primary effort in the area of the laser device involves demonstrating the feasibility and scalability of the hydrogen fluoride cylindrical chemical laser and associated optics. The Alpha laser will provide these demonstrations. A major beam control effort is the Large Optics Demonstration Experiment (LODE). LODE has addressed the generic technical issues associated with the ability to sense and control the high-energy laser wavefront in a dynamic environment. Complementing LODE is

the Large Advanced Mirror Program (LAMP) which has culminated in the fabrication and test of a 4-meter-diameter segmented space mirror. Other technical issues relating to acquisition, tracking, and pointing will be discussed later because they are the focus of a common project responsive to the needs of all the directed energy concepts.

Demonstration and validation of SBL technology will primarily occur in the Zenith Star project, which integrates the Alpha laser; LAMP; LODE beam control; and the ATP/FC technologies in a series of high-power ground and space tests. Zenith Star will ensure that the SBL remains a viable candidate for future deployments. The Zenith Star space experiments complete much of the Dem/Val phase for the space-based chemical laser.

To date, the SBL concept has been defined in a series of conceptual design studies predating the SDI Program. These extensive trade studies have led to a technology base development program that began in the late 1970s and is currently providing the most mature DEW technologies. FY 1989 activities demonstrated that major subsystems are ready to support integrated tests on the ground and system-level tests in space by the mid 1990s.

6.2.3 Neutral Particle Beam

The goal of the NPB technology project is to develop a multimission directed energy device that can function as an effective SDS element. The NPB can be used as both a weapon and a discriminator platform. It can destroy missiles and RVs in the boost, post-boost, and midcourse portions of an ICBM's trajectory as well as discriminate objects during the midcourse, as shown in Figure 6-4. The NPB can defend itself and other space-based assets from homing direct-ascent ASATs.

During the discrimination process, accurate state vectors (position and velocity) of the targets can be determined and handed over to space-based or ground-based interceptors. For passive and active discrimination, all the sensors are on the same platform, reducing the amount of data processing because sensor-to-sensor correlation is not required.

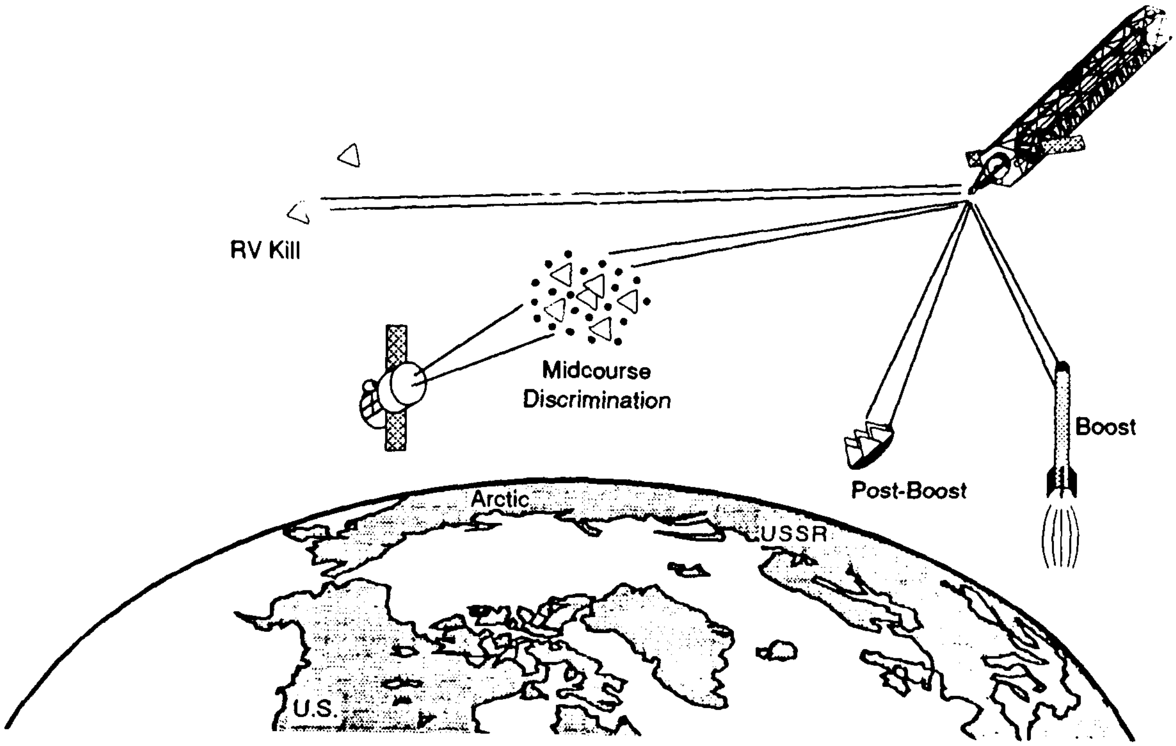
Because the NPB penetrates in depth into the target, it is difficult, if not impossible, to use a countermeasure against it in both the kill and discrimination roles. Analysis and tests have been conducted to verify that the entry level NPB can defeat all proposed countermeasures to the beam-target interaction.

The acquisition strategy for the NPB is summarized in Figure 6-5. The NPB technology development is divided into three areas—component technology development, integration of these component technologies in ground demonstrations, and, finally, space demonstrations to address space operability issues. The component technology development (addressed in Chapter 7) has proceeded well.

Technology Advancements

Projects are now in place to perform the ground integration of these components. This will be accomplished using the ground test accelerator (GTA), the continuous-wave deuterium demonstrator (CWDD), and the power system demonstrator (PSD). The GTA will demonstrate performance with hydrogen at low duty factor. The CWDD will provide continuous wave (CW) operation with deuterium. The PSD will integrate space-traceable power technology.

Figure 6-4
Space-Based Neutral Particle Beam Concept



The GTA is a space-traceable design and will be built in two phases. The first phase, GTA-24, provides the first complete integration of an NPB beam line. The energy will be 24 million electron volts, and results will be integrated in the Pegasus space experiment detailed design. The GTA will be operated in a pulsed mode. The second phase will be the construction of the GTA High Energy (see Figure 6-6).

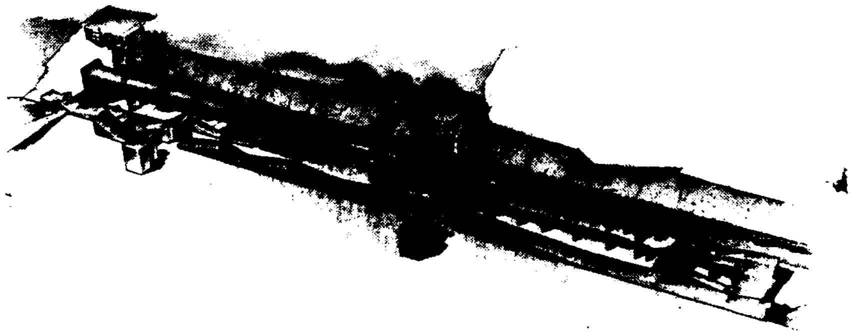
The CWDD is also a space-traceable design that operates in the CW mode. The CWDD will provide the integrated subsystem to address the thermal management issues associated with CW operation and will develop the technology for operation with deuterium as an alternative particle to the hydrogen used in the GTA. Building the CWDD to address the CW operation has resulted in a significant cost savings in the overall project. Operating the GTA CW to address CW operation would have added significantly to the overall development cost.

Non-nuclear power component technologies (see also Chapter 7) will be integrated in an NPB PSD by the mid 1990s. The power systems on the GTA and CWDD are not space traceable. The PSD enables space-traceable power technology to be integrated in the NPB.

Figure 6-5
NPB Acquisition Strategy Summary

- Utilize existing accelerator facilities for component development
  - Accelerator test stand—Los Alamos (Accelerator)
  - Neutral beam test stand—Argonne (Beam sensing and control)
  - NPB test facility—Brookhaven (Neutralizer and beam sensing)
- Build ground integration facilities to show concept feasibility
  - Ground test accelerator (GTA)
  - Continuous-wave deuterium demonstrator (CWDD)
  - Power system demonstrator (PSD)
- Conduct space experiments based on proven ground technology
  - BEAR: Component Technology—Ion source, Radio Frequency Quadripole, Neutralizer
  - Pegasus: GTA-24/ATP
- Transition technology from laboratory to industry by establishing cooperative efforts
  - Component technology and BEAR: Lab design, industry manufacture
  - GTA: Lab lead with industrial partner
  - CWDD: Industry design and build at lab
  - PSD: Industry design and build
  - Pegasus: Industry design and build

Figure 6-6
Artist's Concept of the GTA High Energy



The rocket-borne beam experiment, BEAR (see also Chapter 4), provided initial information on space operability of the NPB. Pegasus, a follow-on space experiment with low to medium risk, is being planned to further address these issues. The GTA-24 and CWDD will provide the technology base for the acquisition, tracking, and pointing. The goal of the Pegasus space experiment is to address those NPB issues that can be addressed only in space.

Chapter 7

Technology Base

Chapter 7
Technology Base

Sustained and focused technology advances are required to develop and maintain a viable strategic defense system (SDS). Accordingly, the SDI Program strategy balances both basic research and focused technology development with system development. Advances that have resulted from these balanced technology efforts are necessary to ensure a thoroughly reliable defense and serve to maintain viability of the Phase I SDS against potential Soviet responses. Aggressive pursuit of growth technologies is guided by the goal of forcing the Soviets to use expensive, complex countermeasures to the SDS with an increased uncertainty of success. Visible demonstrations of technology achievements also have potential for enhancing the arms control process by displaying U.S. options for improving SDS mission capability over time.

To sustain the balanced basic research, focused technology, and system development approach, an investment strategy is applied to technology base efforts by concentrating on the following three major elements:

- Continue work on mature technologies at a pace sufficient to support demonstrations in the early and mid 1990s.

- Aggressively pursue growth technologies with the greatest leverage for maintaining a viable SDS against a potential Soviet response.

- Encourage prompt exploration of new initiatives by reserving a small but significant portion of the budget for such investigations.

The technology base program covers the entire spectrum of technology activities. It includes integrated experiments to accomplish multiple objectives, including feasibility and scalability of technical achievement; fundamental laboratory research to provide the flow of new ideas into the technology base; and conceptual studies, phenomenology investigations and experiments, and data collection projects to support the entire effort. The technology base activities are guided by system performance specifications and goals derived from concept definition and systems analysis activities.

The technology base directly supports Phase I SDS demonstration and validation (Dem/Val) tests and full-scale development (FSD) prototypes. Its growth technologies, analogous to those supporting Phase I, support the advanced concepts and have the potential to maintain and/or improve the mission capability of the SDS. They also yield advanced growth in performance or cost reduction for both Phase I elements and advanced concepts. Its innovative technologies seek to achieve "breakthroughs" or "quantum leaps" to improve the performance of the SDS.

The interaction between technology base and individual element development is key to meeting the demands of the Department of Defense (DOD) development cycle. This interaction occurs in two phases. First, in the early stages of element development, the technology base is focused on performance goals (not specifications) that are defined by systems analysis and Dem/Val activities. The technology base schedules are dictated by a combination of available resources and the progress of technology. Second, in the mature stages of system element development, the

technology base is concentrated on meeting detailed performance specifications and element schedules that are focused on the design, fabrication, and test of the prototype and the eventual production of the element.

The following sections provide a comprehensive description of the Strategic Defense Initiative Organization (SDIO) technology base projects. For each project or task, the technology goals and major activities are described. Where appropriate, an assessment is given of the effort's capability to support FSD.

7.1 Sensor Technology

Sensor technology base efforts are designed to support FSD decisions for Phase I and follow-on SDS sensor elements with respect to achieving surveillance, acquisition, tracking, and discrimination performance requirements. There are six sensor technology areas: signal processing, passive sensor technology, radar technology, laser radar technology, phenomenology, and discrimination.

7.1.1 Signal Processing

Signal processing is an essential part of all SDS space assets that contain sensors (e.g., Ground-Based Surveillance and Tracking System [GSTS], Boost Surveillance and Tracking System [BSTS], Space-Based Surveillance and Tracking System [SSTS], and Brilliant Pebbles [BP]). Since its inception, the signal processing project has focused on providing the technology necessary to perform signal and data processing in space. The hostile environment of space and the requirement for real-time processing of large volumes of data generated by SDS sensors present formidable, but surmountable, obstacles. The radiation environment of space damages and destroys electronic devices, and cosmic rays can change data stored in space-based computer memories. Discharge of a nuclear device introduces radiation hazards to which electronics are also vulnerable. Sensitivity of focal plane arrays (FPAs) to nuclear particle debris requires complex, computationally intensive algorithms to compensate for "noise," which shows up later in the processing flow as false targets.

Special materials and techniques are required in the electronics design and are incorporated in the manufacturing process to mitigate the effects of these natural and man-induced hazards. Spacecraft weight restrictions force computer designers to minimize power consumption to keep the power system small. Components must be reliable and capable of being repaired or reconfigured remotely. These factors force compromises in design of military spacecraft electronics that are not necessary in commercial electronic systems. Large FPAs generate enormous data streams which must be processed in real time. On-board processing of these data requires small, fault-tolerant, low-power, radiation-hardened computers with a processing capability beyond anything yet attempted on a military spacecraft. Robust algorithms are required to evaluate large threats, determine individual threat object positions and velocities, ascertain missile types, generate state vectors, and predict impact points.

The sensor signal processing project is working toward development and implementation of technologies necessary to overcome obstacles to real-time processing in space. It is composed of three developmental projects. The hardened large-scale integrated (LSI) project is dedicated to developing radiation-hardened, silicon-based circuits and memories such as analog-to-digital converters, random access memories (RAMs), and high-power converters. These silicon-based technologies include bulk silicon, silicon-on-sapphire, and silicon-on-insulator. By using these technologies, the hardened LSI project produces LSI and very large-scale integrated circuits (VLSICs) for use by applicable SDI elements. These devices are hardened for total dose,

transient radiation, neutrons, x-rays, and single-event upset exposures. The components of the hardened LSI project will also be used by both the space-based, real-time signal processing and radiation-hardened space subsystems as needed.

The space-based, real-time signal processing project will develop high-throughput; fault-tolerant; and low-size, low-weight, and low-power processors and processor architectures. These devices are required to be both reconfigurable and autonomous. This project also develops software for real-time spaceborne operation. The devices developed under this project will be provided to the radiation-hardened space subsystems project for space qualification. This project will develop space-qualified subsystems composed of processors, memories, buses, and interfaces for flight systems. Figure 7-1 highlights some of the key devices resulting from the project activities.

Figure 7-1
Sensor Signal Processing Technology Project Highlights

DEVICE/PROJECT	DESCRIPTION	APPLICABLE ELEMENT/ EXPERIMENTS
Advanced Monolithic Wafer-Scale Integration	Combines high-throughput processing and memory on a single wafer allowing low power implementation of algorithms that remove false targets induced by nuclear debris	SSTS, GSTS
Radiation-Hardened 32-Bit Processor	High-performance, radiation-hardened processor provides building block for space-based computers requiring 32-bit precision	BSTS upgrade, SSTS
Radiation-Hardened Static Random Access Memory	Radiation-hardened memory provides the prime building block for all space-based electronics systems	All SDI elements, on-board signal/data processor on Midcourse Space Experiment
Generic Very High-Speed Integrated Circuit Space-borne Computer	High-performance, radiation-hardened processor offers high utility to many SDI projects requiring high-throughput processing	BSTS, applicable to all SDI projects
Analog-to-Digital Converters	Advanced high-speed, radiation-hardened converters required to digitize analog output of FPAs	All SDI elements using FPAs

7.1.2 Passive Sensor Technology

FPAs, cryocoolers, and optics are the key technology thrusts for developing cost-effective passive surveillance sensors that operate above and below the horizon in the boost, midcourse, and terminal layers of an SDS. Major technical goals for focal planes are superior performance in a nuclear radiation environment, producibility, and affordability; for cryocoolers the goals are reliability, power efficiency, long life, and manufacturability; and for optics the goals are operation in a nuclear radiation environment, producibility (especially of large optical structures), and affordability.

The FPA project will develop the necessary technology in passive sensor materials, detector arrays, readout devices, FPA hybrids, and FPA modules. This project encompasses proof-of-concept validation of new approaches to pilot line production and demonstrations of baseline performance. The primary FPA

development supporting surveillance sensors observing targets above the horizon (primarily SSTS and GSTS) is under the Hybrid With Advanced Yield for Surveillance (HYWAYS) project. This project is pursuing detector and readout technology advances in maintaining performance while operating through nuclear environments, increasing operating temperature of detectors, and increasing sensitivity performance of the hybrid under low background and moderate background conditions. In addition, technology developed under the Precursor Above-the-Horizon Sensor (PATHS) project is used in HYWAYS for a pilot line run to produce and test 30 hybrids a month for 6 months and to develop a cost and yield model to allow extrapolation to other production rates. Technology presently under development in HYWAYS needs to be incorporated into a pilot production line after the advanced performance is demonstrated. A focal plane assembly integration technology project, including focal plane processing, also needs to be initiated. These efforts would be initiated by FY 1992 to support FSD in FY 1994.

A separate project is developing a solid-state photomultiplier (SSPM) device capable of counting single photons in the long-wavelength infrared (LWIR) spectrum. These very high-sensitivity detectors potentially have better hardness than impurity band conductors (IBCs). The SSPM is in the proof-of-concept phase and is expected to take less time to develop than the IBC devices because of its similarity to IBCs. A program analogous to IBC development would allow support of FSD in 1996.

The Manufacturing Technology (ManTech) project is the primary FPA development supporting surveillance sensors that observe below the horizon. The purpose of this joint Air Force and SDIO project is to demonstrate production readiness for mercury cadmium telluride focal planes to be used in the BSTS. It focuses on the necessary fabrication controls to improve yield and performance. Radiation testing will be performed at contractor and government facilities to validate the hardness of FPA-related components and subsystems. As discussed in Chapter 4, the ManTech project has made significant progress toward enhancing the producibility of detectors to meet the BSTS FPA specification.

The primary cooler project, the Prototype Flight Cooler (PFC), focuses on the requirements for LWIR sensors such as SSTS. The goal is to demonstrate an 8.5°K 2.5-watt cooler with 5-year life and 0.95 reliability. The cooler is planned for life testing starting in FY 1992. SDIO successfully transferred the PFC project to the Air Force SSTS Program Office to allow further development. The cooler will demonstrate long-term reliability during the planned 10,000-hour accelerated reliability test scheduled to be completed in FY 1994. The 65°K cooler development effort is to provide a 10-year long-life cooler for medium-wavelength infrared (MWIR) and short-wavelength infrared (SWIR) sensor applications, such as BP. The flexure Stirling technology offers long life (10 years) and high operating efficiency. Three contracts have been awarded for trade studies and conceptual designs to be completed in FY 1991. These technologies could support FSD in FY 1992.

The interceptor community generally uses one-time "blow-down" or Joule Thomson (J-T) coolers. Two technology development efforts, one in quick cool-down J-T and the other in mixed gas research, are aimed at increasing acquisition range by reducing the cool-down time and enhancing detector sensitivity by lowering its temperature. At current technology development rates, these advanced technologies would be ready to support an FY 1996 FSD. Advanced concepts to improve reliability focus on reduced complexity and higher efficiency of mechanical components. The most promising technologies for increasing reliability by using nonmoving parts are thermoacoustic drivers, pulse tube coolers, and sorption coolers. High efficiency is

expected from the magnetic cooler work, currently in testing, and through examination of a static nonmoving-parts magnetic device.

Radiation-hardened, lightweight, mechanically strong and producible optics components need to be developed for surveillance and interceptor sensors. The optics project includes mosaic sensor technology; hardened optical components; test, characterization, and calibration of mosaic arrays; and sensor modeling and signatures. New methods to rapidly fabricate radiation-tolerant optics include specially multilayered hardened overcoated silicon carbon substrates, single-point turning of beryllium (Be) to final figure, replicated optics from a master mandrel, and amorphous Be overcoating of Be substrates to provide very low-scatter surface. A compatible set of these techniques is being prepared for inclusion in a wide-field-of-view breadboard optical bench that will be tested in a cryogenic environment. The wide-field-of-view project is designing and producing hardware, to be laboratory tested, which will demonstrate technology and producibility of the large and lightweight optics needed to support SSTS-sized space sensor arrays. This development is critical to reducing the number of sensors needed to cover the search field. Proof-of-concept optical designs will support FSD in FY 1991; hardened-mirror concepts could support FSD in FY 1993; and low-cost hardened mirrors capable of rapid production to support FSD should be available in FY 1995.

7.1.3 Radar Technology

Microwave radar technology efforts support the design of SDS active radar sensors for both midcourse and high-endoatmospheric discrimination of reentry vehicles (RVs) from decoys; they also support interceptor missions. The goals of radar technology are to develop large phased radar components that precisely operate at high power levels and wide bandwidths on a large number of targets in a hostile environment. Additional goals are to develop and produce large arrays to reduce costs and to develop and test robust discrimination algorithms. A combination of analytical and component hardware investigations are being conducted to support a deployable, full-scale ground-based radar in the late 1990s. These include fast-scanning narrow beam widths, short-pulse durations, and wide-bandwidth waveforms allowing operation in nuclear and electronic threat environments. Discrimination algorithms are being developed and tested which utilize the long-range, high-resolution, and precise measurement capability of large microwave radars. Successful demonstrations of the radar technology will support a Milestone II decision. The technologies will be incorporated into an FSD prototype.

Radar technology activities address the system-level issues of design, cost, producibility, discrimination, and countermeasure vulnerability. The design activity consists of the development of an expert, computer-aided design workstation. The workstation provides the capability to conduct radar design, performance, and cost trades. To reduce cost and enhance producibility, array architectures are being developed. These array architectures consist of wide-band microstrip array elements, which are low in cost and can be produced in quantity; an integrated subarray design based on layered board construction techniques; a two-axis scan diode lens; and distributed-array concepts. Solid-state transmit/receive module development is also being pursued.

In the discrimination area, the focus is on providing waveform processing components, including high data acquisition systems, and radio frequency (RF) pulse forming and waveform processing using both digital and acousto-optical techniques.

In addition, countermeasure mitigation techniques are being developed, including adaptive-array configurations, main-lobe cancellation, and netted multiband concepts.

7.1.4 Laser Radar Technology

The overall goal of laser radar technology is to support the fire control and active discrimination functions of the SDS. Responsive threats against the SDS will likely require both passive and active discrimination techniques. The program develops both low power and high power systems, which can be used against both small targets (e.g., RVs, decoys) and large targets (e.g., buses, boosters) from low earth orbit and medium earth orbit (MEO). Both nonimaging and imaging concepts have been developed. The longer-wavelength carbon dioxide (CO_2) laser radar systems are generally more advanced than the shorter-wavelength solid-state laser systems, but the shorter-wavelength systems may provide great savings in weight, higher efficiency, reduced size of optics and beam control systems, and more rapid beam retargeting capability. This technology effort also includes the surveillance large optics technology project which is a comprehensive program to develop and demonstrate technologies for fabricating, testing, and maintaining large surveillance optics for space applications.

The project will demonstrate the feasibility of its technologies with a series of experiments and demonstrations. The Low Weight Kinetic Energy Weapon Active Tracker (LOWKATER) project has developed a state-of-art design and has begun construction of a nominal 100-watt, 250-kg, 1.5-cubic-meter CO_2 laser radar system capable of providing excellent range and velocity measurements on small targets located up to 1,000 km in range, and on larger targets up to 3,000 km in range. This laser radar system is suitable for discriminating RVs from decoys upon release from the post-boost vehicle (PBV). Discrimination is provided by the accurate track files that can be generated based on the precise range and angular measurements of the objects. Its conservatively designed CO_2 laser radar requires a minimal amount of development. An innovative rapid optical beam steering system (Roving Fovea) has been developed which will permit one laser radar satellite to view many PBVs in rapid succession. This laser radar system will be available for FSD in mid 1992.

The solid-state laser radar effort emphasizes development of diode-pumped slab laser technology, which will demonstrate a 10-watt system this year and a 100-watt system within 2 years. The Strategic Laser Technology (SLT) project is developing higher-power CO_2 laser radars for MEO-based missions. Applications include nonimaging precision range and Doppler measurements of target kinematics for discrimination, tracking, and far-term imaging technologies. An important part of this project integrates rapid optical beam steering subsystems, such as the Roving Fovea and coherent array concepts, with laser transmitters developed under the SLT project. The Firepond laser radar facility provides an advanced CO_2 laser radar system, coupled with existing x- and L-band imaging and tracking radars, for ground-based measurements of discrimination phenomenology using rocket-launched targets in space.

The surveillance large optics project addresses key issues throughout the entire life cycle of a large mirror, from material selection through maintenance of high optical performance after telescope deployment as part of an orbiting surveillance platform. Major research areas include aspheric surfacing, beryllium and ceramic substrates, coatings, contamination control, and survivability support.

7.1.5 Phenomenology

Phenomenology efforts collect and analyze optical and radar signature data, and model phenomena required by systems developers to design and evaluate SDS elements. Background and plume phenomenology data are required to design boost-layer sensors so they can differentiate targets from hard earthlimb backgrounds. Booster and PBV signature data and plume/booster hardbody characteristics are also required to develop acquisition, tracking, and identification algorithms. Midcourse sensors must identify RVs from a large and varied set of targets and masking devices. Data on potential penetration aids, and even on debris, are required so that passive optical discrimination techniques will be viable in the near term. Radars must also identify RVs from targets and masking devices. The need to intercept targets high in the atmosphere and in space has placed new emphasis on augmenting the available background and target signatures to support radar design and development.

Backgrounds

The Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS) 1A, a Shuttle-based cryogenic infrared (IR) sensor, is primarily designed to collect earth and earthlimb background data from space. CIRRIS 1A is manifested on Space Transportation System (STS) 43 and is scheduled for a January 1991 Shuttle launch. The orbit and mission duration of the Shuttle mission will enable CIRRIS to collect background data on a global scale.

The purpose of the Infrared Background Signature Survey (IBSS) is to observe and characterize the spectral and radiometric signatures of several space objects and phenomena critical to the design and operation of SDS sensors and interceptors. IBSS is also manifested on STS 43.

The Space Infrared Imaging Telescope (SPIRIT) II sensor is similar in design to CIRRIS 1A with two important differences: the spatial resolution of SPIRIT II is better than that of CIRRIS, and the SPIRIT II sensor is launched from a sounding rocket. SPIRIT II is scheduled for launch in October 1991 and will collect about 6 minutes of data during a period of high atmospheric activity that will provide a stressing natural background against which SDS sensors must discriminate. The Electron Accelerator Experiment (EXCEDE) III, a sounding rocket experiment that will excite the upper atmosphere with a high dose of electrons, approximating some aspects of a nuclear event, will provide the data important for the validation and extension of nuclear predictive codes. The sensor module on EXCEDE III will measure optical emissions from ultraviolet (UV) through IR, with the highest resolution being in IR.

The Three Color Experiment (TCE) is an add-on to the existing focal plane array on an existing experiment. It provides two additional spectral bands. TCE was primarily intended to collect data on bright clouds that can create a clutter problem for a BSTS, BP, or midcourse sensor. Data will also be collected on upper-stage booster emissions.

The Visible/Ultraviolet Experiment (VUE) instrument began to obtain data in October 1989. VUE collects ultraviolet and visible data on missile signatures, the natural background, and space objects.

Targets

The ARGUS aircraft is an NC-135A that has been modified to function as an airborne platform for calibrated optical sensors that operate in visible through LWIR wavebands. These sensors include visible and IR imagers, an IR spectrometer, and

visible cameras for photodocumentation. Upgrades are planned to the existing sensor suite to improve the sensitivity and spectral coverage of the UV/visible and IR imaging systems. Improvements are planned to existing acquisition and tracking systems and data recording systems. Longer-range plans also include the acquisition of an SWIR through LWIR spectrometer and a UV/visible spectrometer. These upgrades are necessary to ensure that ARGUS can successfully meet all assigned mission objectives and collect calibrated plume, target signature, and intercept data in the UV through LWIR wavelengths.

The High Altitude Learjet Observatory (HALO) is a type-35 Learjet that carries calibrated optical sensors operating in UV through MWIR wavebands. The existing sensor suite includes a UV imager, wide and narrow field-of-view visible imagers, and an infrared imaging system (IRIS). An upgraded IRIS has been developed with extended coverage in SWIR through LWIR wavebands and increased sensitivity by a factor of 1,000. The new IRIS and existing sensors will be integrated into a larger aircraft, currently identified as a Gulfstream IIB, during FY 1990. The flexibility afforded by the larger aircraft and improved sensors will ensure that HALO will continue to collect valuable phenomenology and interceptor kill assessment data on assigned SDI missions.

The Midcourse Space Experiment (MSX) is a multiyear spacecraft assigned to collect data and address specific functional issues essential to midcourse sensor development (e.g., SSTS, GSTS). Data collection will focus on backgrounds, targets, and the near-spacecraft environment. Functions to be demonstrated will include tracking, bulk filtering, and discrimination. MSX design, construction, and operations will also provide experience in integrating state-of-the-art technology. Launch is scheduled for FY 1993.

The Exoatmospheric Discrimination Experiment (EDX) is a series of intercontinental ballistic missile (ICBM) flights from Vandenberg Air Force Base to the U.S. Army Kwajalein Atoll area. The deployed threat representative targets will be viewed by both optical and radar sensors over most of their flight paths. The principal optical sensor to be employed is an advanced design using state-of-the-art optics and focal planes. The first of nine target flights is scheduled to occur in late FY 1993.

The targets will also be viewed by the MSX sensors and Kwajalein radars. EDX is the only program that will provide the high-resolution, high signal-to-noise data on known targets that are required for discrimination algorithm development and testing in support of GSTS. It will also demonstrate some key GSTS technologies.

Models

The Strategic Scene Generation Model (SSGM) is under development to directly support system needs. The SSGM will produce standardized two-dimensional natural and nuclear background scenes for evaluation and development of sensor algorithms and system designs. The modular SSGM architecture will contain all relevant government standard codes and databases for scene construction. This activity has supported the BSTS project in FY 1988 and FY 1989.

7.1.6 Discrimination Technology

A fundamental sensor system-level need is to discriminate lethal RVs from decoys as well as from fragments and debris of ballistic missiles and other objects in space. To this end, the primary goal of the Discrimination Technology project is to seek and exploit signatures of the ensemble of objects in threat clouds released by missiles.

Three types of sensors can make discrimination measurements: passive, active, and interactive. Passive sensors measure IR, visible, and UV energy emitted by targets. Active sensors (microwave and laser radars) transmit small amounts of energy to targets with a portion scattered back to the sensor. The advantages of passive sensors are that they generally have longer effective discrimination ranges and cannot be detected by objects being observed and discriminated. Active sensors enable measurement of targets that might otherwise be hidden and allow control of time, rate, and form at which energy arrives, thus allowing direct measurement of target parameters such as range and velocity. Interactive discrimination uses passive and active sensors coupled with a high energy active source. The source, either a laser or a particle beam being developed under the Directed Energy Weapon (DEW) program, perturbs the target in some predetermined manner such that its velocity is changed or its thermal signature is modified. These changes are then detected by the active or passive sensor in the interactive system. Details on the technology base efforts in passive, active, and interactive sensors were provided earlier in this chapter.

Discrimination is being approached through target motion studies and data analysis for the development of new discrimination techniques. Phenomenology experiments and data collection efforts (see Section 7.1.5) are key inputs to the development of discrimination techniques and algorithms. Discrimination projects include technique development, real-time testing of algorithms, test planning, data assessment, sensor selection, and target definition. Discrimination efforts using multispectral techniques in passive sensors continue to evolve along with active techniques using laser and microwave radars. A real-time imaging and discrimination test bed has been established for testing and evaluating real-time algorithms.

7.2 Command Center/System Operation and Integration Functions Technology

The Command Center/System Operation and Integration Functions (CC/SOIF) technology effort contains projects that support the Command Center Element (CCE). Its purpose is to develop the technology required to support a responsive, reliable, survivable, and cost-effective CC/SOIF. The project seeks to satisfy technology needs in five areas: algorithms, software engineering, processors, network concepts, and communications. These technology efforts must provide the required system properties of reliability, testability, durability/survivability, robustness, security, component producibility, and availability. Figure 7-2 identifies the activities involved in the five technology areas discussed in this section.

7.2.1 Algorithms

The SDIO Engineering Deputate vigorously pursues algorithm technology for the CC/SOIF. Because of the unique inputs, functions, and environments, tested and proven algorithms for at least some functions are not likely to be developed outside of the SDI community. Algorithmic approaches that emphasize parallel processing are being investigated to achieve the stressing performance requirements. Work is being performed in all the areas identified in Figure 7-2 to develop and test an integrated set of algorithms that will meet the unique requirements of the SDS.

Figure 7-2
CC/SOIF Technology Base Activities

Algorithms • Track Initiation and Maintenance • Discrimination • Situation Assessment • Weapon Target Assignment • System Reconfiguration • Performance Evaluation • Defense Tactics • Data Fusion • Decision Aids • Kill Assessment	**Software Engineering** • Software Engineering and Development Environments • Producibility • Testability • Security • Survivability • Robustness • Evolvability
Network Concepts • Network Control and Management • Message Routing • Multiple Media • Protocol Engineering • Network Reconfiguration • Switching Technology • Security • Reliability • Survivability	**Processors** • Security • Large Memory • Fault Tolerance • Power/Size/ Weight • Reliability • High Throughput • Real-Time Operating System **Communications** • Robustness • Laser Links • Security • 60 GigaHertz RF • Data Rates • Fiber-Optic Networks

7.2.2 Software Engineering

The volume of software needed for SDS will be larger than for any system developed to date, posing unprecedented requirements on reliability, maintainability, adaptability, and performance. An SDS software policy has been created to address these software engineering issues and to provide guidance on appropriate practices for developing mission-critical FSD SDS software. A software center has recently been established at the National Test Facility, Falcon Air Force Base, Colorado, and is being staffed to disseminate the software standards and policies and identify key software technology thrusts in software engineering.

7.2.3 Processors

SDS processor requirements are being addressed through a variety of ongoing hardware development programs. CC/SOIF projects include the development of advanced architecture processing systems, processor security evaluations, and real-time and distributed operating systems. Alternative parallel processor architectures are also being addressed. These projects will draw on the device technology research described earlier, including efforts in scalability and radiation hardness.

7.2.4 Network Concepts

Communications networking technology that provides for survivability, adaptability, security, high bandwidths, multimedia, and fault tolerance is being developed. The current technology development activities will develop network control algorithms, message routing algorithms, and network processing equipment. Major projects in networking include those for defining security requirements, evaluating bandwidth requirements and routing, and studying network packet switching in support of communications network emulation.

7.2.5 Communications

Space-to-space, ground-to-space, and space-to-ground communications are required to meet the functional, operational, and technical requirements of the SDS. Space-to-space cross-links are particularly critical and are the least mature. The use of laser communications provides greater link security, higher data rates, reduced size, weight and power requirements, and reduced frequency management requirements. The technology for RF links is mature for the lower frequencies, but survivability considerations dictate the use of extremely high frequency millimeter-wave (MMW) frequencies. Both laser technology and 60 gigaHertz RF technology have seen recent progress arising from continuing SDIO-sponsored research, including work on agile beam lasers and agile beam phased arrays. Ground-based communication needs are also being addressed with investigations into secure fiber-optic networks.

7.3 Interceptor Technology

Interceptor technology projects are organized for systematic component development, integration, validation, and infusion into the various SDS elements. The technologies in development support Phase I and follow-on interceptors, including the Ground-Based Interceptor (GBI), Brilliant Pebbles (BP), and High Endoatmospheric Defense Interceptor (HEDI). Interceptor component technologies share several critical goals: high performance, low weight, low life-cycle costs, mass producibility, nuclear hardening, and long service life. Because cost is usually driven by weight, especially for space-based interceptors, the highest-priority goal of most projects is to achieve order-of-magnitude improvements in performance and miniaturization. Advanced interceptor technology components are integrated into miniaturized lightweight exoatmospheric and endoatmospheric projectiles. These projectile technologies are applicable to SDS space- and ground-based interceptor requirements. To validate interceptor technology, state-of-the-art advances in simulation, ground testing, and free-flight testing are required. Beyond component development, there are technology goals for integration, evaluation, and flight testing.

7.3.1 Component Technology

All SDS interceptors have a seeker to acquire the target during flyout, an inertial unit for guidance during flyout, avionics to translate data received from the seeker and the inertial unit into usable information for interceptor guidance commands, propulsion to translate the control logic to trajectory changes and accelerate the interceptor to its target, and some type of fire control to assign targets. A description of each of these interceptor component technologies follows.

SDI seeker technology encompasses the entire spectrum of wavelengths, including UV, SWIR, MWIR, LWIR, millimeter-wave (MMW), and dual mode (IR and radar). SWIR seeker technology applies primarily to warm targets reentering the atmosphere in the terminal phase; MWIR and UV seeker technologies apply primarily

to hot boost-phase targets; LWIR seeker technology applies primarily to cold targets in the midcourse phase; and MMW and dual-mode seeker technologies apply primarily to short-range theater defense.

UV technology is being considered as an alternative to IR for finding booster hardbodies in the presence of hot plumes. Specific SWIR technologies under investigation include aero-optics, nuclear-hardened scanning arrays, and a laser rangefinder for fusing. Specific LWIR technologies under investigation include 128 x 128 nuclear-hardened staring arrays, analog signal processing, binary optics, and flash-cooled optics. (Producibility of nuclear-hardened FPAs and readout electronics, also being addressed in the technology base, was discussed earlier in this chapter.)

Projects in avionics technology address a number of stressing requirements. To minimize interceptor data rates, a full set of on-board image processing algorithms are required. These include sensor array nonuniformity compensation through multiple target thresholding, target acquisition, tracking, and aimpoint determination. The interceptor must simultaneously perform on-board trajectory corrections and attitude control in response to maneuvering and nonmaneuvering targets at closing velocities of up to 20 kilometers per second. One of the projects is developing high-density packages for signal processors with high throughput requirements. Another project is developing nuclear-hardened signal and data processors to complement hardened seeker technologies. Current software development projects concentrate on adaptive algorithms to enable target selection in the midst of clutter and radiation. Topological features of measured data, which enable seekers to locate a missile in the presence of its much brighter and irregularly shaped plume, are being exploited as a data source for algorithm development. Other algorithms capitalize on shape or spectral discrimination to find a true target in closely spaced objects.

The greatest emphasis in inertial technology has been on cost, size, and weight reductions for moderate performance inertial measurement units (IMUs). The primary IMU development is a solid-state inertial sensor based on resonant fiber-optic gyro technology. This project takes advantage of technologies that have been developed over recent years for the semiconductor industry to reduce costs by implementing batch processing and low labor-intensive manufacturing techniques.

SDI propulsion technologies are categorized as either divert or axial. Divert propulsion controls flight direction and orientation, and axial propulsion accelerates the interceptor toward the target. Divert technology projects are investigating solid, liquid bipropellant, and liquid monopropellant alternatives. High-temperature solid motors stress materials technology, requiring advanced development in valves and nozzles. Monopropellant units have the potential to be very low cost and simpler in design than bipropellants, but require performance improvements to be competitive. Axial booster technology has been worked in several areas, including liquids, gels, and fast-burn solids for ground-based interceptors and high-performance liquid and solid stages for space-based interceptors. Compared to solids, liquid boosters with gel sustainers have the potential to be reduced by 50 percent in weight while meeting safety requirements for handling. Space-based axial propulsion technology development includes extremely high-performance propellants; high-strength graphite fiber composite motor cases, tanks, and nozzles; and a pilot production plant for advanced propellants.

SDI fire control technology is focused primarily on laser radars for precision target tracking. The principal project is LOWKATER (see Section 7.1.4). Another project addresses nonmechanical beam steering techniques based on liquid crystals and acousto-optics. Nonmechanical designs enable tracking of multiple targets over a very large area without gimbals, mirrors, and high slewing rates.

7.3.2 Integration Technology

As appropriate "families" of component technologies mature through the brassboard verification level at independent government testing facilities, consideration is given to the technologies required to integrate the new components into kill vehicle and booster designs.

The integration technology project will coordinate efforts to design, develop, integrate, and validate advanced miniaturized component technologies into high-performance, lightweight, kinetic kill vehicles (KKV) to support kinetic energy weapons (KEW) FSD decisions. Typical integrated projectiles consist of four major subsystems: seekers, IMUs, avionics, and propulsion; they weigh less than 3 kilograms. An example of an integrated projectile is the Lightweight Exoatmospheric Projectile, which will serve as the pathfinder for space- and ground-based KKVs. Technical issues will be verified through a series of validation tests on the ground and in space. Component/subsystem-level testing is used to update and refine computer simulations and performance estimates.

Validation technology projects support an integrated testing methodology that has been developed to validate the interceptor simulation models with hardware test data. Independent government evaluation of contractor-developed hardware components/ subsystems/systems will be performed at the simulation, ground test, and flight test levels. A closed-loop testing approach consisting of digital simulation, emulation, hardware-in-the-loop simulation, hover testing, and free-flight demonstrations enables higher confidence levels of predicted interceptor performance.

Digital emulation technology projects include a Kinetic Digital Emulation Center (KDEC) that is being developed by the U.S. Army. This facility will have the capability to provide real-time simulation/emulations of interceptor performance in end-to-end, one-on-one engagements. KDEC includes advanced chips necessary to emulate the highly parallel processing needed to achieve real-time speeds to accurately model advanced technology interceptor components.

Hardware-in-the-loop technology projects include the Kinetic Hardware-in-the-Loop Simulator (KHILS) that enables the government to cost-effectively ground test seekers, IMUs, and avionics subsystem performance in realistic target engagements. KHILS is currently developing a medium-bandwidth flight motion simulator, a high-performance infrared-laser scene projector, and an environmental chamber. These upgrades will enable accurate testing of GBI, BP, and HEDI supporting technology components. KHILS testing will fulfill service and congressional requirements for independent government performance evaluations prior to key decision points.

The National Hover Test Facility (NHTF) is responsible for validating the interceptor propulsion engines (divert and attitude control systems) and characterizing the vehicles' structural stability. The facility provides the capability to hover test, validate performance, and identify and resolve flight anomalies in vehicle propulsion and avionics hardware and software at a fraction of the cost of a space experiment. The NHTF has been validated by conducting the first series of free-flight hovers against a tumbling target. The facility will support interceptor vehicle preparation; preflight calibration and measurement; in-flight telemetry, tracking, and control; target simulation; range safety; vehicle recovery and refurbishment; and data acquisition, reduction, and analysis.

The final tier in the technology validation approach is free-flight testing in realistic environments. A 5-year flight test program has been initiated to flight qualify interceptor components and integrated KKVs. Finally, the combination of standardization of payload carriers and functional performance flight testing enables low-cost flight tests in accordance with the Commercial Space Launch Act of 1984.

7.4 Directed Energy Technologies

Directed energy technology efforts are grouped into five project areas: free electron lasers; chemical lasers; neutral particle beams; acquisition, tracking, pointing, and fire control; and nuclear directed energy weapons.

7.4.1 Free Electron Laser/Ground-Based Laser

There are four key technology activities supporting the GBL: (1) the device scaling project, which will progress from the initial output power needed for proof of principle to the continuous power levels needed for initial deployment; (2) the propagation and beam control project, which must perfect an adaptive optics subsystem to correct distortion of the laser beam caused by uneven heating of the atmosphere, atmospheric turbulence, and other phenomena; (3) the space optics and beam control project, which requires the development and producibility of precision large optics and figure control in a dynamic environment, including wavefront sensing; and (4) the acquisition, tracking, and pointing (ATP) project, which must provide the capability to acquire and track an uncooperative target and precisely point the weapon beam, as well as provide beam alignment for establishing and maintaining the alignment between the ground station and the relay and mission mirrors. The ATP project will demonstrate that a lethal laser beam can be transmitted through a distribution beam control subsystem. To demonstrate that these technologies can be combined to produce a fully integrated GBL, a major demonstration called the Ground-Based Free Electron Laser Technology Integration Experiment (GBFEL TIE) will be conducted.

While the free electron laser (FEL) technology is primarily focused on ground-based laser concepts, it also includes technologies unique to space basing. Major areas of research include the radio frequency linear accelerator, which was recently chosen over the induction linear accelerator for the GBFEL TIE; beam control; optics; systems engineering and integration of the TIE; and a supporting technology base for GBL, including space relay and mission mirror assets. Another technology area deals with the development of a space-based FEL that will be able to address the strategic defense missions of boost-layer intercept and midcourse interactive discrimination. This technology will also provide an alternate technology path to future high brightness requirements.

7.4.2 Chemical Laser/Space-Based Laser

Chemical laser technology is primarily focused on SBL concepts. SBL subsystems include the laser device; beam control; acquisition, tracking, pointing, and fire control (ATP/FC); and space platform. The device extracts the high-power beam from a reaction of hydrogen and fluorine. The project should progress from its present capability in a ground-test configuration to the ability to generate near diffraction limited high power in a space-compatible configuration. The beam control subsystem corrects for aberrations introduced by the device and the high-power optical elements, establishes the boresight of the beam and focuses it on target, and moves the beam from target to target. The beam control project has developed a means of sampling the outgoing wavefront and analyzing it with a wavefront sensor to provide corrections to the deformable mirrors which control the wavefront. During retargeting, the system

must maintain excellent beam quality, and in the optics area the capability to produce large adaptive optics is being developed. The ATP/FC subsystem acquires the target, selects and maintains the aimpoint during irradiation, and assesses target damage. ATP/FC subsystem technology effort is discussed in Section 7.4.4. Integration of these technologies must occur to demonstrate a low-loss capability at high-megawatt power levels.

Key SBL technology developments for entry-level weapons platforms include the Alpha laser, the Large Advanced Mirror Program (LAMP) mirror, and the Large Optics Demonstration Experiment (LODE) beam control subsystem. All of these technologies are scalable to SDIO's performance goals for an entry level system. Starlab Shuttle experiments will establish the technical feasibility of the required ATP functions. The Complementary Space Experiment and the Zenith Star project (described in Chapter 6) will investigate SBL integration issues which require a space environment for their resolution. In the near term, Alpha, LAMP, and LODE technologies will be integrated in a series of ground experiments to investigate and validate the performance of high-power beam control subsystems. Options for space experiments are maintained with designs for integrating SBL experimental hardware into a research spacecraft.

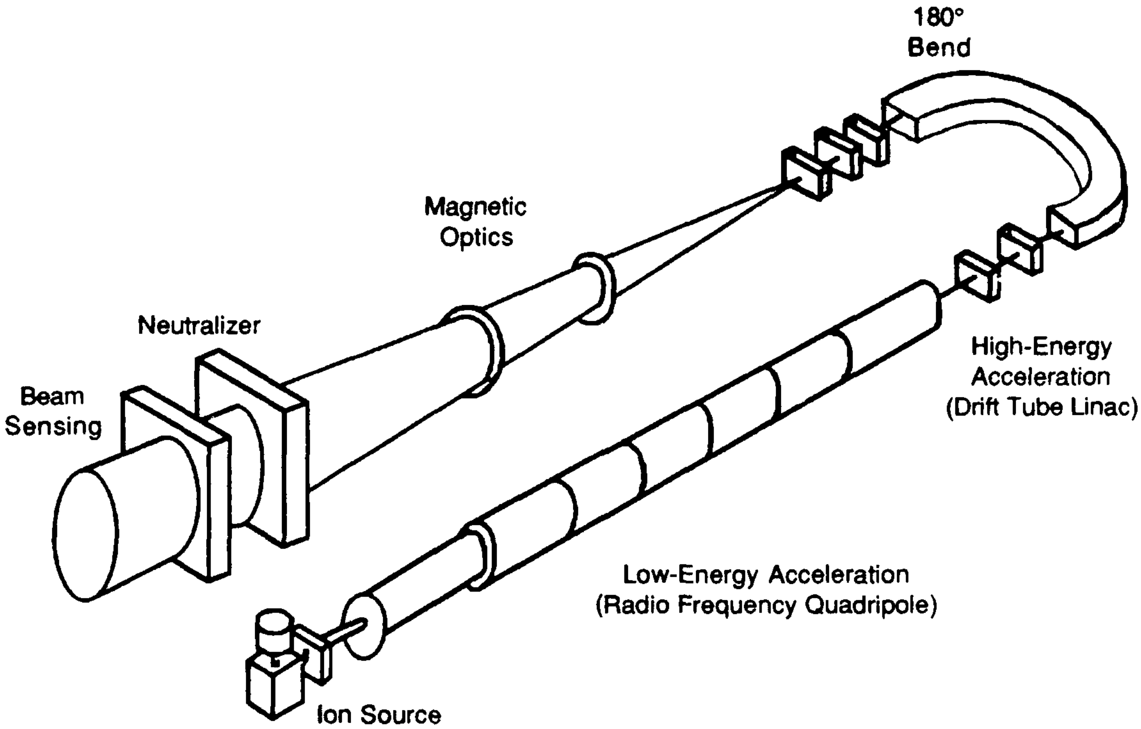
Growth technologies that preserve the modular nature of a space-based chemical laser deployment and enable order-of-magnitude increases in platform brightness are being developed. These technologies include short-wavelength chemical lasers, phased-array telescope and device coupling, and nonlinear phase conjugation.

7.4.3 Neutral Particle Beam

Accelerator technology to implement an NPB is making rapid progress. NPB accelerator technology builds on experience of the high energy physics community's efforts that have been ongoing for almost 40 years. As the American Physical Society (APS) indicated in its 1985 report on directed energy weapons, NPB development issues are engineering issues. The need is to build lightweight, high brightness, low divergence accelerators, with the magnetic optics to keep these beams focused while minimizing divergence growth and aberrations. Lightweight efficient neutralizers and accurate beam steering technology are also required.

NPB beam line components are illustrated in Figure 7-3, while hardware which has been tested is shown in Figure 7-4. Ion sources have been developed with the brightness and duty factor to meet weapon requirements, but both brightness and duty factor have not been met simultaneously. Technology projects are in place to develop ion sources which simultaneously meet both requirements. The Soviet-developed concept of the radio frequency quadripole (RFQ) provides lightweight technology for the low-energy portion of the accelerator which bunches and begins to accelerate the negative ions to a couple of million electron volts (MeV). Acceleration of the particles to weapon level is completed by the ramped gradient, cryogenic drift tube linear accelerator sections. These components have been integrated and tested on the accelerator test stand at Los Alamos National Laboratories. A space qualified ion source, with electronics, RFQ, gas neutralizer and solid state power supplies was recently built, tested, and flown in space on the Beam Experiment Aboard Rocket and addressed basic space operability issues. The magnetic optics shown were designed and built at Los Alamos and recently tested on the Argonne National Laboratory's 50 MeV neutral beam test stand (NBTS). The wire shadow beam sensing hardware, also built by Los Alamos, is currently being tested in conjunction with the magnetic optics on the NBTS at Argonne. Lightweight efficient foil neutralizers have been developed and tested for thermal loading and survivability. Through these develop-

Figure 7-3
Beam Line Components



ments, all the issues raised with respect to the NPB in the APS DEW report have been addressed.

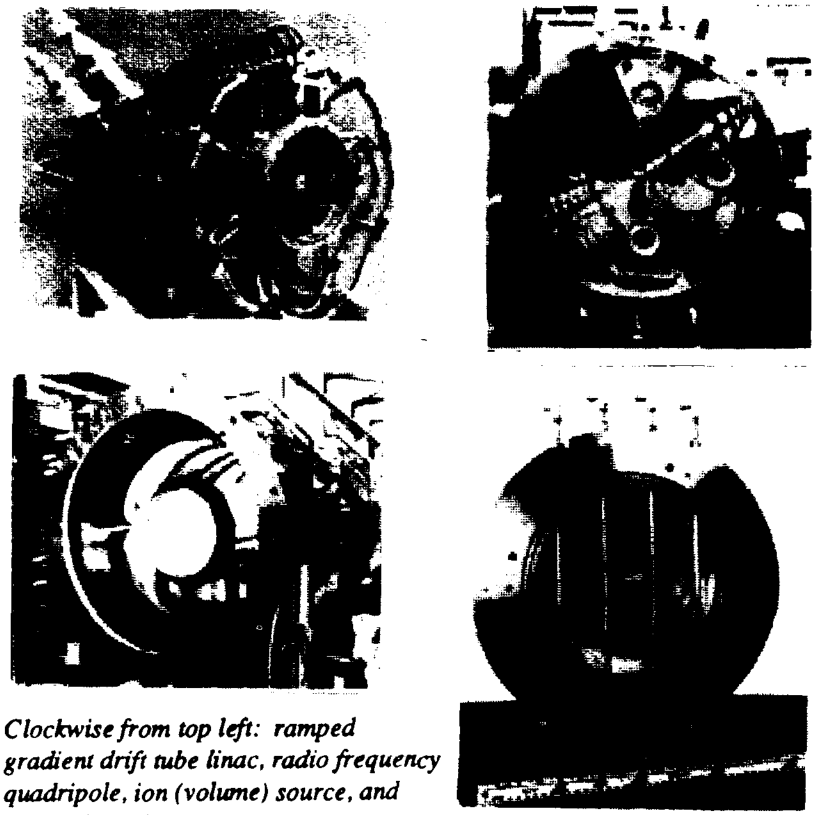
Power requirements for near-term NPB platforms can be met with power technology available within the near term within cost and weight constraints established by the NPB concept definition studies. Technologies to be used include turbogenerators, fuel cells, klystrodes, and solid state RF power being developed in the SDIO power technology project.

7.4.4 Acquisition, Tracking, Pointing, and Fire Control

The ATP/FC technology effort supports all DEW concepts. Major goals for the project include: demonstrating technology for initial acquisition of boost or midcourse targets against complex backgrounds (missile exhaust plumes; earth, atmospheric, and celestial radiance sources); very rapid retargeting of the weapon beam in order to maximize multitarget engagement rates; precise pointing of the beam at high angular tracking rates in the presence of disturbances and countermeasures; and autonomous control of multiple-target engagements.

Efforts in the ATP/FC project are in several related areas. ATP/FC space experiments are under development to address both generic and concept-specific issues that can be adequately resolved only in space. These experiments include the Low-Power Atmospheric Compensation Experiment (LACE), the Relay Mirror Experiment (RME), Starlab, and the ATP portion of the Zenith Star experiment. Efforts within the ATP/FC technology base address major tracking/pointing component performance issues, and the development of technologies for advanced concepts.

Figure 7-4
NPB Technology Progress



Clockwise from top left: ramped gradient drift tube linac, radio frequency quadripole, ion (volume) source, and magnetic optics

7.4.5 Nuclear Directed Energy Weapon Technology

Research on NDEWs is being pursued to provide a base of knowledge concerning such weaponry that would permit the U.S. to better judge potential Soviet capabilities, and to provide the basis for a U.S. NDEW capability should it be needed later for SDS follow-on phases. The NDEW research path is based on theoretical and computational development in concert with underground nuclear tests and related laboratory experiments. The DOD and Department of Energy (DOE) cooperative effort is conducting mission analyses as well as exploring platform engineering concerns.

7.5 Other Key Technologies

Supporting technology projects fall into two categories. One set of key technologies focuses on survivability, lethality, and countermeasures. They enhance functional survivability of potential strategic defense force elements in hostile environments and reduce uncertainties in the DOD's capability to predict vulnerability of enemy targets. The second set resolves SDI-unique problems in power and power conditioning, and materials and structures. Research in this area is critical to the development of a survivable and effective SDS. Combined, these technology projects provide a formidable source of technology development and assessments of technology requirements, tactics, and strategies; they ensure survivability of the SDS to mission completion in the face of determined defense suppression attacks. In addition, they

provide essential data on weapon-target interaction (for kill) and probe-target interaction (for interactive discrimination) to assess SDI Program requirements. Equally important, they develop lethality criteria that determine performance requirements for candidate weapon concepts.

7.5.1 Survivability

The Survivability Technology project responds to the approved threats and system requirements generated by SDIO Engineering. Working closely with the element projects, it develops a suite of survivability technologies which respond to the technology needs expressed by those projects. It then demonstrates the technologies through an integrated series of aboveground and underground tests, flight tests, and simulations called INSURE (Integrated Survivability Experiments); and assists the elements in the infusion of appropriate technology approaches.

The primary goal of the survivability project for FY 1990-92 is to develop and demonstrate survivability technologies required for Phase I SDS. These technologies will ensure that the SDS can withstand a determined defense suppression threat (DST) and retain the functionality to meet or exceed the Joint Chiefs of Staff SDS mission requirements.

Technology projects include development of passive component hardening; shielding against nuclear, RF, and laser threats; as well as active countermeasures that aid in avoiding the threat. An integral part of this project is the demonstration of these technologies through aboveground and underground testing, the use of models and simulation tools to gain confidence in technology solutions, and integration of technology with element designers. These technologies are being developed to make SDS hard to find, but, if found, difficult to kill.

The survivability technology project consists of four major Service-executed technology activities: (1) the objective in the operational survivability area is to ensure that efforts being expended in developing active and passive SDS survivability enhancements are compatible with the plans, procedures, and infrastructure of the organization that will actually operate the SDS after deployment; (2) the survivability technology project support activity provides support to the survivability technology development/demonstration project by performing the general and specific actions needed to manage all aspects of the project; (3) the near-term technical objectives of the U.S. Army System Survivability project are the characterization of survivability technology for ground-based elements through simulation, hardware-in-the-loop demonstrations, and the conduct of aboveground and underground tests. Integrated effects tests for survivability are the simulation and test activities required to demonstrate in a "system context" the survivability and operability of the Army elements of SDS; and (4) the objectives of the U.S. Air Force System Survivability project are to structure and implement a survivability technology project for space-based SDS element concepts; develop innovative survivability technologies; demonstrate the utility of candidate survivability technologies based on a synergistic building block approach against a combined DST at high levels of integration; and begin analysis, development, and demonstration of far-term element survivability technologies.

7.5.2 Lethality and Target Hardening

The lethality and target hardening project assesses the ability of Phase I and follow-on weapon concepts to destroy current and responsively hardened threat ballistic missiles and warheads. It is a high-leverage technology base activity that provides essential data for SDS weapon system designs such that large "safe-side" overdesign

and accidental catastrophic underdesign can be avoided. It addresses weapon effectiveness issues and weapon-target interaction signatures (observables). Put simply, this project answers two questions, "What does it take to kill the target?" and "What can be seen when the target is hit or killed?" It is a comprehensive research project that studies damage effects created by SDS weapons concepts and predicts the corresponding vulnerability of Soviet targets.

Research in KEW effects focuses on providing design criteria to the weapon developers, and developing enhancement techniques that ease guidance requirements, or reduce warhead weight. Directed energy research is structured to characterize the basic phenomenology in a weapon-target engagement. Each program addresses the weapon energy on the target and the subsequent material/structural response of the target through modeling and validation experiments.

In the KEW lethality project, experiments are being conducted to characterize the minimum damage to an RV aeroshell that will ensure that an RV will be destroyed when reentering the earth's atmosphere. We have shown that with a percentage of the aeroshell removed, the RV will violently destroy itself. Destroying RVs by removing the aeroshell can be done with much less mass than destroying RVs through warhead dismemberment. These results are of high value to the GBI, HEDI, and BP developers because these criteria directly affect required performance parameters.

The Theater Missile Defense (TMD) lethality project is assessing reactive agents and aerodynamic dispersion as a means of destroying chemical warheads. We have demonstrated lethality in both modes against this significant TMD threat. The TMD program is proving to be an effective mechanism for transferring the results of SDI research to the conventional weapon technology base.

The sympathetic detonation project is assessing whether the high explosives in a nuclear warhead, when impacted by space-based kinetic energy weapons, will "throw" fragments large enough and fast enough to detonate the high explosives in the neighboring RVs on a PBV. A chain reaction (sympathetic detonation) could potentially destroy all RVs on a PBV. The lethality project is also conducting assessments to determine whether sufficient damage would occur on neighboring RVs for aerothermal kill on reentry.

The thermal laser lethality project is assessing the effectiveness of laser weapons against hardened liquid boosters and near-term solid rocket hardening techniques. Large-scale hybrid hardening and composite bottle test series at the Mid-Infrared Advanced Chemical Laser are supporting assessments to determine the energy needed to cause observable failures of scale-model ICBM and submarine-launched ballistic missile boosters. Targets being assessed include graphite epoxy composite bottles, metal tanks overwrapped with graphite epoxy, pressurized bare metal spheres to emulate PBV propulsion tanks, and pressurized spheres with composite material overwraps. The weapon characteristics and countermeasures being investigated in the thermal laser lethality program will support design of laser weapon systems.

In the impulse laser project, the sensitivity of laser lethality to a wide range of pulse energies, pulse lengths, and wavelengths is being investigated. The NOVA laser at Lawrence Livermore National Laboratory is being used to simulate the target material temperature and density regime of interest to the impulse laser project. This is the first step in reducing the laser/target coupling uncertainties and providing predictions for NDEWs. Also being determined is the fluence needed to cause catastrophic kill in a firing rocket experiment. Codes and subscale tests indicate that rockets may be

destroyed at much lower impulse levels than those previously determined because of internal fuel spallation when the rocket is firing.

The particle beam lethality project characterizes NPB-induced failure levels on electronic components and missile guidance hardware. Vulnerability of a safing, arming, fusing, and firing system found in RVs through tests at the Brookhaven National Laboratory particle beam accelerator is being assessed. Initial results demonstrate that electronic kill can be accomplished using entry-level NPB concepts. These results are not only specific to RV kill, but also can be generalized to system kill of PBV computer, guidance electronics, and other mission-critical electronic "boxes." The particle beam project is also assessing degradation and subsequent dysfunction of ICBM accelerometers, part of a missile guidance subsystem necessary for accurate missile flight. Indications are that significant guidance and total dysfunction are induced with reasonable dwell times associated with NPBs currently under consideration.

7.5.3 Power and Power Conditioning

Power and power conditioning requirements fall into four general categories: baseload power, multimegawatt technology, pulse power and power conditioning, and ground power. Initial research focused on component technology improvement, but integration of these components is now beginning to demonstrate subsystem feasibility.

The Phase I space-based elements (BSTS, SSTS, BP) will need continuous baseload power (a few kilowatts to a few tens of kilowatts) that is survivable to hostile DSTs. The Survivable Solar Power Subsystem Demonstrator (SUPER) will establish the baseline solar power designs using presently available technologies. The objective of the SUPER program is to develop and space qualify a solar-based, survivable power system that is scalable for 2- to 40-kilowatt applications at various altitudes and inclinations. The system must be survivable to pellet, projectile, laser, x-ray, and microwave threats. The power system will integrate all necessary technologies: solar concentrators, gallium arsenide photovoltaic cells, nickel-hydrogen batteries, radiation-resistant power circuitry, and lightweight, high-temperature structural and thermal control materials. A flight test scheduled for early FY 1994 is necessary because many survivability innovations have no previous flight qualification. Two contractors are competing in the program. A third option specifically for BSTS is cost shared with the BSTS project office. High-payoff technology development is also under way for insertion into SUPER; this includes multiband-gap solar cells that have 30 percent or more efficiency, and sodium-sulfur batteries that have more than twice the energy density of nickel hydrogen.

As follow-on space-based elements begin to emerge, baseload power will be required at levels that cannot be practically met via solar technologies. This growth in the face of increasing DSTs can be satisfied by the SP-100 space nuclear power option because of its mass advantage and inherent hardness capability over scaled-up solar power approaches. This DOE and National Aeronautics and Space Administration (NASA) cost-shared nuclear subsystem can satisfy baseload power requirements up to hundreds of kilowatts with significantly enhanced hardness. The uranium nitride fueled reactor is cooled by pumped liquid lithium loops. Thermoelectrics convert reactor heat to direct current. The reactor core is being fabricated and will be tested in Hanford, Washington. Thermionic components also under development will offer higher conversion efficiency exceeding 10 percent, whereas thermoelectrics are 4 to 5 percent efficient.

Multimegawatt burst power (tens to hundreds of megawatts) could be required to power weapons and active sensor and discrimination elements during engagement. Two magneto-hydrodynamics (MHD) concepts are under development to provide this power. The objective is to assess feasibility of applying MHD to space-based applications. Fuel cells, batteries, and cryogenic generators are also under development. A joint project with the NPB was integrating these technologies into a complete power subsystem that would have established feasibility and demonstrated technology readiness.

Pulse power and power conditioning technologies transform the electrical characteristics of the prime power source to match the requirements of the weapons and sensor systems. Order of magnitude improvements in power handling and power density are required to enable space-based directed energy elements. Technologies in this category are energy storage devices, high-power switches, converters, and sources to energize RF accelerators.

A project to develop Superconducting Magnetic Energy Storage (SMES) is in place; its goal is to establish the feasibility of this technology for the GBL. SMES, which is partially funded by the Electronic Power Research Institute, also holds great promise for utility load leveling applications. In FY 1990, this project will be transferred from SDIO to the Defense Nuclear Agency where it will be funded and managed. SDIO will continue to provide technical direction.

7.5.4 Materials and Structures

The goal of the materials and structures (M&S) project is to provide critically needed advances in materials and structures technologies for Phase I and follow-on phase SDS elements that will reduce risk, support SDS performance goals, and improve affordability. M&S research goals include reducing weight and cost, and increasing producibility, of ground- and space-based vehicles; enhancing sensor tracking and weapon fire control performance; assuring the availability of space-durable materials; and providing high-performance communication and NPB components using newly discovered high temperature superconductivity (HTS) materials.

While M&S project development activities emphasize Phase I systems requirements, long-lead technologies are also being addressed in support of follow-on systems. Technology developments culminate in demonstrations in which SDS element prime contractors set the technical targets and actively participate to assure effective technology infusion. M&S technology demonstrators are coordinated with system Dem/Val schedules and prime contractor design verification testing. In some cases, M&S demonstrators are an integral part of system Dem/Val. This approach assures that maturation of M&S technologies are timely and fully support system FSD.

The project is focusing on several major technical thrusts. These include: lightweight structural composites to enhance performance of interceptors and provide dimensionally stable and precision structural elements for sensors and DEW beams; structures and control technologies required to achieve precision pointing of sensors and DEW beams mounted on lightweight and inherently flexible space platforms in dynamic environments; space environmental effects testing to extend on-orbit life of materials for space-based SDS elements; and tribological materials that provide long life for precision sensor gimbals, cryocoolers, and other mechanical moving assemblies; and optical materials that address critical performance and producibility issues for sensor windows and hardened baffles. Also under development are HTS components for high-performance MMW communication and radar components, low-loss RF accelerator cavities to significantly reduce NPB and FEL power and weight

requirements, and superconducting on-FPA signal processing to enhance sensor performance.

7.6 Space Transportation

The deployment, assembly, maintenance, and servicing of an SDS will require a substantially increased space launch capability. Based on results of architectural studies conducted over the last few years, the focus of the SDIO Space Transportation project was the Advanced Launch System (ALS). The objective of the ALS was to satisfy launch requirements of all users, including DOD, NASA, and national sectors by the year 2000. ALS has a goal of reducing by a factor of 10, as compared to the present Titan IV, the cost of delivering cargo to low earth orbit. The specific ALS configuration was to be determined at the Milestone I Defense Acquisition Board review scheduled for 1990. However, the scope of the current ALS program has been reduced to an advanced launch technology development program only. Vehicle design and operation concept definition work has been terminated. The remaining technology program will demonstrate those long-lead technologies necessary for a vehicle decision in the late 1990s.

The current advanced launch development program is a joint DOD-NASA effort and will demonstrate those long-lead technologies required to build an efficient, low-cost launch vehicle. Technologies to be demonstrated include propulsion, avionics, structures, aerothermal protection, and operations, as shown in Figure 7-5. Daily management of this program is performed through the Air Force Space Systems Division.

Alternative space transportation architectures and technologies have been examined. Alternatives include, but are not limited to, expansion of existing systems, development of new dedicated launch vehicles or some combination of the above. As the Phase I mission model weight-to-orbit decreases substantially, studies show that it becomes increasingly possible to use an expansion of the current set of launch vehicles to deploy Phase I. New heavy-lift launchers will be required for follow-on systems.

7.7 Innovative Sciences

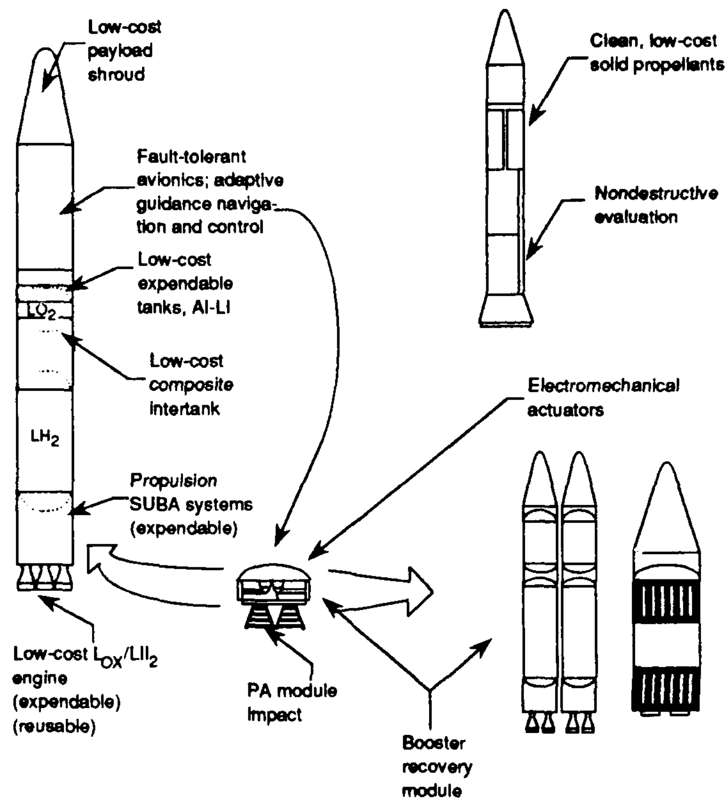
This section describes two types of projects: Innovative Science and Technology (IST) and Small Business Innovative Research (SBIR).

7.7.1 Innovative Science and Technology

The IST project is that part of the technology base effort that encourages prompt exploration of new initiatives. As such, its goal is to exploit innovative technologies seeking "breakthroughs or quantum leaps" that would improve the capability of an SDS to perform its specific assigned functions.

The project provides funds for advanced research in fundamental science and engineering, focusing particularly on exploitable technical areas applicable to ballistic missile defense. The IST office sponsors fundamental research in six areas: (1) advanced high-speed computing, (2) materials and structures for space applications, (3) sensing and discrimination, (4) advanced space power, (5) advanced propellants and propulsion, and (6) directed/kinetic energy concepts. This sponsorship, which is limited by available funding to a relatively small portion of potential participants, is exercised and carried out by 40 science and technology agents. These agents, in turn, enlist the services of innovators in many different scientific areas. Basic research results are structured to expand the forefront of science and technology, with ultimate

Figure 7-5
Advanced Launch System Vehicle Technologies



transfer of such results to tasks in other parts of the SDI Program. IST research is conducted throughout the scientific community in universities (including those with a significant ethnic or minority student population), government and national laboratories, small businesses, and large industries.

7.7.2 Small Business Innovative Research

Pursuant to Public Law 97-219, the SBIR project provides seed capital for technology innovation that will help the federal government and foster commercialization of federal research and development (R&D) at small U.S. businesses.

SBIR rewards innovations by small U.S. firms where seed capital is needed to mature the technologies enough to attract users and venture capitalists. SDI spreads 1.25 percent of its extramural R&D among hundreds of firms developing technology innovations that help SDI and also hold promise of commercialization. Competition is keen; only one-fifth of the candidates get the $50,000 Phase 1 awards, and only 40 percent of those receive the $500,000, 2-year duration Phase 2 awards. SDIO probably selects the highest percentage of Phase 1 awards among all federal agencies.

The current allocation will continue in accordance with PL 97-219, although new legislation is under consideration to increase it.

SDIO completed 20 Phase 2 projects in FY 1989. Further development of these concepts by SDIO, DOD, and other users may follow as Phase 3. Each Phase 2 contract was managed by a government expert who knows where the firm's technology fits into the SDS and the areas where it would fit into other DOD programs. SDIO is developing programs to help connect the Phase 2 successes with other government and commercial opportunities. Section 7.8 and Appendix E discuss this effort further.

7.8 Technology Applications

This section describes SDIO's efforts to facilitate transfer of SDI-developed technology to the private sector, federal agencies, state and local governments, and universities to benefit the nation's technology base and economy and to support U.S. defense and R&D efforts. Appendix E contains a detailed summary of these activities.

A number of congressional and presidential initiatives have been enacted since the early 1980s to encourage scientists, entrepreneurs, and academicians to use federally developed research as a source of innovation for new private and public sector products and processes. Among these initiatives are the Stevenson-Wydler Act of 1980, Small Business Innovation Act of 1982, Federal Technology Transfer Act of 1986, Presidential Executive Order 12591 of April 1987 entitled "Facilitating Access to Science and Technology," National Defense Authorization Act of 1987, 1988 Omnibus Trade and Competitiveness Act, and National Defense Authorization Act of 1988.

Building upon this foundation, SDIO established an Office of Technology Applications to implement a program that makes SDI technology available to other federal agencies and qualified U.S. corporations, small businesses, entrepreneurs, universities, and state and local governments. The objectives are, first, to identify and catalogue emerging SDI technologies with potential applications for private and public sector R&D and commercial efforts. Second, the program provides interested and qualified individuals and organizations with access to information about SDI technologies so that they can discuss technical details with the developers and make the necessary business arrangements to accelerate technology transfer.

SDIO's Office of Technology Applications also has management responsibility for the Medical Free Electron Laser (MFEL) program. Initiated at the direction of Congress in 1985, the MFEL program in FY 1991 will implement the results of the FY 1990 competition to establish a minimum of seven free electron laser medical research centers to adapt FEL technology to applications in medicine, photobiology, surgery, and materials science. The MFEL program is national in scope and draws upon the resources and expertise of more than 20 universities and teaching hospitals to further FEL research.

7.9 Special Projects

The goal of Special Projects is to identify and bring together near-term concepts that have unique aspects that may provide high-leverage results to advanced systems and technologies. Working closely with all offices of the SDIO, Special Projects examines emerging new concepts for their required ground or flight test needs. Based on common or similar experimental test requirements (not similar system interfaces), these concepts are fused together into integrated experiments. This approach provides a test bed for multiple experiments which, when viewed independently, may not warrant the investment of a dedicated flight test. When combined, however, the aggregate

experiment provides considerable multidisciplined results and resolves a substantial number of near-term technology implementation issues for advanced or special systems applications.

Special Projects continues to carry four major test project areas. In last year's report, the Delta Star spacecraft and Black Star sounding rockets were indicated as projects that would be fully executed in FY 1989. Both projects were launched on schedule. However, the unanticipated extended life of Delta Star carries the project's success into FY 1990. All project technical objectives relate to the operation of near-term experiments in realistic environments for the generation of data necessary for the Phase I and follow-on architectures and technologies.

Delta Star Satellite

Launched in March 1989, this spacecraft serves as an orbital platform for collection of rocket exhaust plume signatures and multispectral background data on the earth, earth limb, and aurora. In addition, the spacecraft is equipped with a materials experiment package that measures environmental effects of near-space on specific materials and optical coatings, and a laser illumination detection system, which is used as a laser warning system. The spacecraft was built to a design life of 180 days, which was surpassed on 20 September 1989. The spacecraft's useful life exceded the design life by over fifty percent.

Advanced Implementation Technologies

Advanced implementation technologies involve the integration of near-term, high-risk advanced guidance, astronavigation, and pointing into a miniaturized and lightweight system. FY 1990 tests include the launch and operation of an improved, autonomous orbital test vehicle. This experiment, LOSAT-X, will be launched on the next available LOSAT Delta. The initial candidate vehicle (LOSAT Delta launched in February 1990) placed in orbit the LACE and RME spacecraft. SDIO will perform the mission director and launch operations functions for the LOSAT Delta and conduct joint operations of the LOSAT Delta launch vehicle, Delta Star spacecraft, and the LOSAT-X payload.

Hybrid Kill Mechanisms

Hybrid kill continues FY 1989 research on a unique combination of kinetic and directed energy mechanisms into a single weapon concept. Research to date has advanced the theoretical physics understanding of the existing test device. FY 1990 funding is oriented toward extended operation and realistic tests. If successful in FY 1990, the system tested on the ground may be repackaged for ballistic space test in FY 1991.

Energetic Interaction Studies

The successful Black Star project provided very specific results on the potential for fuel releases and higher energy payloads to cause background modification. As a follow-on to Black Stars 5 and 6, at least one high-energy ballistic payload will be executed in FY 1990. This experiment will gather physical measurements of the interaction potential, an improvement to spectral measurements performed on the Black Stars.

Chapter 8

Theater Defense

Chapter 8
Theater Defense

This chapter discusses SDI projects that have developed theater or regional missile defense concepts (architectures) and related technical progress and programs. These include missile interceptor experiments, analytical tools (e.g., test beds), technology experiments, foreign technology support of some theater programs, the relationship of theater and strategic defense, and the utility of directed energy weapons in a theater role.

8.1 Concept and Project Overview

The Theater Missile Defense (TMD) program builds on theater architecture studies previously accomplished and in progress, technology demonstrations and tests, and the development of test beds to form the cornerstone of technical alternatives for systems that could provide a defense against theater-class ballistic missiles. This program defines mission objectives and derives candidate architectures against ballistic missiles that threaten U.S. forces and our allies in NATO, the Middle East, the Western Pacific basin, and other regions.

Concept definition, architecture studies, and technology research are conducted through government-to-government agreements with our allies, and through U.S.-managed procurements with U.S. contractors and multinational contractor consortia. Technology requirements are examined in various analyses, experiments, and hardware test activities to improve technical understanding of the TMD problem and alternatives for defense architectures or components. TMD interoperability is being examined to assess the mutual benefits derived from integrating space- and ground-based defense assets in selected geopolitical areas.

8.2 Special Studies

The TMD Directorate of the Strategic Defense Initative Organization (SDIO) supported a series of architecture studies to develop a better understanding of the missile threat, the need for missile defenses, and the possibility of developing these defenses. These analyses included the bilateral U.S.-U.K. Architecture Study (UKAS), the Theater Missile Defense Architecture Studies (TMDAS), the bilateral U.S.-Israeli Architecture Study (IAS), and the Western Pacific (WESTPAC) Architecture Study. Each study was specifically tailored to cover a region of interest and threat. The UKAS provided a U.K. perspective of the ballistic missile threat to NATO Europe, established a notional architecture to counter the long-range ballistic missile threat, and identified components that could be used in a European defense architecture. Phase VII of the UKAS will examine threat excursions, sensor and weapon system sensitivities, and possible synergism between a European Ballistic Missile Defense Architecture and the U.S. Strategic Defense System (SDS). It also will project the life-cycle cost associated with a proposed architecture. The TMDAS focused on the near-term, short-range ballistic missile threat to the central region of NATO and was completed in August 1989. These studies identified the need for missile defenses and the kinds of architectures that should be evaluated, noting that technology was not a critical issue in this decision process. The IAS examined the

unique threat environment present in the Middle East, developed both near- and far-term notional architectures to counter the theater missile threat, and projected life-cycle costs to develop and deploy such architectures. The Israelis are now evaluating experiment and test bed development with respect to architecture performance. The recently initiated WESTPAC Architecture Study is investigating and characterizing the threat to Japan and the associated sea lines of communication (SLOCs).

The current Special Studies program is focused on continuing the WESTPAC Architecture Study, a United Kingdom Artificial Intelligence Discrimination project, a Knowledge-Based System Data Fusion project, the SDS/TMD Interface project, and the Israeli Systems Engineering and Integration (SE&I) project, as described in the remainder of this section. It will also support the development of defense architecture alternatives based on TMDAS results and threat excursions.

WESTPAC Architecture Study

The WESTPAC Architecture Study has developed a missile threat characterization for the Western Pacific region. The study, being conducted by two multinational consortia, will result in a proposed architecture for the missile defense of Japan, its associated SLOCs, and other assets of U.S. interest. The architecture will be designed as an autonomous system capable of being integrated with the U.S. SDS. The threat suite includes ballistic, cruise, and air-breathing threats. The study has two phases. During the first phase (completed in November 1989), it was determined that the region is indeed threatened by missiles; therefore, a missile defense is required. Several defense architectures were proposed and the near-term threat characterized before a preliminary construct was selected.

The Japanese prime contractor provided an interim report of directed energy technology and a separate study of Japanese command, control, and information (C^2I) technology. In accordance with Section 217 of the FY 1988 Appropriation Act, these deliverables were identified as having value added to the contract worth $1.7 million because the technology might have application to missile defense, and U.S. understanding of Japanese C^2I is mandatory for accurate architectural development. Hence, the United States is paying $3 million for $4.7 million worth of effort.

During the second 1-year phase, which will begin in January 1990, the contractors will define and evaluate ICBM and third world threats, reevaluate their preliminary architecture, select an architecture to meet near-term defense requirements, and recommend a hardware acquisition plan. (Their product will include an assessment of the costs associated with their proposed defense design.)

Artificial Intelligence (Target) Discrimination

The problem of distinguishing a threatening reentry vehicle (RV) from decoys and other penetration aids will be evaluated by this cooperative U.S.-U.K. project. The project is examining the utility of artificial intelligence techniques to provide a robust, real-time discrimination solution. The project will be based on *a priori* knowledge of offensive missile payloads and will focus on situations where class and object distinction are potentially inaccurate due to threat countermeasures and sensor ambiguity. As a threat raid develops, the initial sensor data will be used to validate the *a priori* database as an additional measure to ensure credibility. As specific patterns develop within the threat raid, the expert system will learn and hypothesize about the

size, distribution, and classification of the threat. The utility of the framework will be demonstrated during the next year. This U.S.-U.K. program is cooperatively funded on an 80:20 basis.

Knowledge-Based System Data Fusion

The theater commander's effectiveness in a future war may be limited by his inability to obtain timely and high-quality essential information due to the significant increase in data being processsed. This data saturation creates a need for technologies which enable data from multiple sources to be quickly and accurately fused to generate a comprehensive assessment of rapidly developing, complex operations. This cooperative U.S.-U.K. project is composed of two parts: the development of laboratory demonstrators for naval command and control as well as SDI TMD applications, and a supporting research program to examine the utility of parallel computer architectures, human/computer interfaces, validation/specification of Knowledge-Based Systems, database and/or knowledge-base interfaces and planning applications. The combined project will demonstrate the enhanced capabilities available through the exploitation of real-time, knowledge-based, automated support of the fusion of data from disparate sources for the generation of the tactical picture, the subsequent situation assessment, and resources allocation. This work is a follow-on to successful U.K. efforts in the application of knowledge-based system techniques to Navy issues. The demonstrator will be complete in FY 1992. This cooperative U.S.-U.K. effort is supported on a 42:58 cost-sharing basis.

SDS/TMD Interface

TMD architectures could be stand-alone or autonomous with respect to a U.S. SDS. However, most theater analyses indicate the need for space-based support. Typically, only sensors are required to provide enhanced battle management and attack assessment. The special analyses supported here will include an evaluation of the contribution that a deployed SDS might make in the defense of a theater or region, in terms of improved sensor data and possible intercept of some theater-class weapons. The support that theater defense elements can provide to the SDS will also be evaluated; for example, phased theater sensors might provide an auxiliary sensor correlation for strategic assets, and theater ground-based interceptors might play a role in terminal intercepts. These analyses will identify the kind of experiments and/or computer-assisted evaluations that should be conducted to better understand this relationship.

Israeli Systems Engineering and Integration

The Israeli SE&I effort, in support of the Arrow interceptor and Israeli Test Bed (ITB) projects, will perform three major tasks. These include a system design update of the Israeli architecture and its components, a compliance assurance of related technology efforts, and a sensitivity evaluation of an optional defense architecture. The system design update will reassess the theater ballistic missile threat, update the Israeli defense architecture, analyze reports on the operational requirements of the system, its subsystems and elements, and recommend modifications to the architecture. The Israeli SE&I project will evaluate the specifications and all interim results of related technology programs (Arrow, ITB, hypervelocity gun, etc.) relative to the architecture's operational and interface requirements. If appropriate, design changes will be recommended to assure future interoperability, and all pertinent results will be provided to the ITB contractor.

8.3 Interceptors

The TMD interceptors project supports research on theater-class interceptors, interceptor components and subcomponents, and associated technologies as developed by TMD architecture studies and as a part of SDI global objectives. The project is structured with a near-term goal of providing sufficient technical information to enable a user (the U.S. Department of Defense or an ally) to choose among developmental alternatives for countering the theater missile threats. The long-term goal is to develop technologies to support future theater defense requirements as derived by the user and in coordination with overall SDS technologies and system developments.

The project objectives will be accomplished through a number of technology demonstration programs, including the Extended Range Interceptor (ERINT-1), the Israeli Arrow interceptor, and the Tactical High-Altitude Area Defense (THAAD) interceptor, each of which is described below.

ERINT-1

The ERINT-1 project will demonstrate the hit-to-kill capability of a small missile using an on-board radar seeker to guide it to intercept. The missile will be demonstrated against a variety of targets from maneuvering to nonmaneuvering tactical missiles to air-breathing threats at moderate altitude and maneuver. The interceptor is being designed to perform hit-to-kill intercepts of maneuvering targets while maintaining a keep-out altitude. This technology may have application in the augmentation of fielded air defense systems, but could also contribute to the terminal defense of strategic assets against faster RVs. A series of eight flight tests is planned at the White Sands Missile Range and will follow the successful completion of many simulations, including extensive sled tests and hardware-in-the-loop evaluations. The flight tests are currently scheduled to begin in FY 1992. The development and testing of all ERINT-1 subsystems and components have been initiated and are proceeding on schedule.

Arrow

The Arrow is an Israeli-developed missile designed to achieve a near-perfect defense against a missile threat and to perform intercept sufficiently far from the defensive position. This is a cooperative U.S.-Israeli program supported on an 80:20 cost-sharing basis.

The Arrow missile will demonstrate its intercept capabilities against a surrogate tactical ballistic missile. The demonstration will provide considerable engineering data. Three flight tests, to be conducted in Israel, have been scheduled. Extensive laboratory and ground tests will be conducted prior to the start of the flight test program. Delivery of the components required to produce flight-test missiles is ahead of schedule.

Tactical High-Altitude Area Defense

The THAAD interceptor project will develop and test a preferred design for a theater area defense missile to overlay protected-asset defense systems. The missile is primarily designed for post-intermediate range nuclear force theater defense and is expected to operate in the high-supersonic or low-hypersonic speed regime with high agility and to counter the postulated year 2005 and beyond threat. It is being designed to be compatible with existing air defense elements such as fire control systems. The

program includes multiple competitive awards for a 12-month concept definition phase. If the concept definition effort justifies a competitive down-select to one contractor, then a 54-month demonstration/validation phase will follow. The FY 1990 program will develop the basis for initiation of the concept definition phase.

8.4 Theater Missile Defense Test Beds

The potential of a theater defense architecture against short- as well as long-range ballistic missiles from the Soviet Union, Warsaw Pact, or third world countries needs to be examined in detail to evaluate defense efficiency relative to cost before committing scarce resources to a particular technology or set of technologies. The contribution of SDS elements to the theater defense role and the mutual contribution of TMD assets to the strategic battle must also be examined. The SDIO fully supports a computer-based test bed designed to evaluate TMD components as they are developed from concept definition through hardware prototyping. Such a test bed, with a common base of simulation software, and country-unique software at national nodes, will provide the most complete capability for analyses in the U.S. and allied research communities. The Extended Air Defense Test Bed (EADTB) being developed by the U.S. Army Strategic Defense Command (USASDC) for SDIO will be the primary resource for these TMD analyses. A test bed in the United Kingdom will prove compatibility and capability to operate with NATO developers first and provide a tool for joint analyses second. The Israeli test bed will enable the assessment of TMD resources in third world conflicts after complete analysis of the Israeli architecture and its elements. Additional test beds in the United States and selected allied locations would complete the EADTB design goal and create an international evaluation capability for consensus building.

Extended Air Defense Test Bed

The role of the EADTB is to study issues and technologies associated with the implementation of TMD systems. The EADTB integration and U.S. node development effort will perform the necessary integration activities associated with all nodes (U.S. and allied) of the EADTB and develop, operate, and support the U.S. nodes. The EADTB will include a simulation tool to be used by both U.S. and allied agencies to analyze a wide variety of extended air defense issues as they apply to the NATO theater. These issues include the analyses of changes in offensive force threat and tactics and changes in defensive materiel, force structure, doctrine, and training. The initial nodes of the EADTB will be located at USASDC in Huntsville, Alabama, and at the United States Army Air Defense School, Ft. Bliss, Texas, with an option for a node at Ft. Leavenworth, Kansas. Each EADTB node will consist of a collection of data processing hardware and software specifically configured to simulate threat, environment, NATO command and control structures and procedures, and appropriate extended air defense systems. Each node will be capable of stand-alone operation and of networking with other EADTB nodes and other test beds. Each node will support hardware-in-the-loop simulation and associated real-time evaluations. A U.S.-led multinational team will develop the software and hardware foundations for the basic EADTB design. Allies that agree to participate in this project on a cooperative basis will be responsible for their share of costs in hardware and facilities acquisition. The benefits of such a cooperative program will include improved communication and understanding as well as a common database. The need for and design of an integrated EADTB network will also be evaluated.

Israeli Test Bed

The ITB project will develop a stand-alone test bed capability using computer simulation to evaluate Middle East TMD designs as part of TMD against defined threats. The ITB project is a cooperative effort between the U.S. and Israeli governments with a 72:28 cost-sharing basis. It will initially focus on the near-term threat and associated architecture(s). The design will provide for flexibility to accommodate future defense systems and advanced threats. The project will have a concept definition phase followed by a development and integration phase. The evolving test bed capability will include man-in-the-loop and hardware-in-the-loop mechanisms. A list of experiments will be identified for unilateral and/or joint participation under this task. This effort should also be able to support those analyses necessary to evaluate missile defense designs in the Middle East and perhaps in other third world scenarios.

U.K. Test Bed

As previously noted, the EADTB is designed to be used by NATO allies. Several nodes will be established, and the U.K. node, located at the Royal Signal and Radar Establishment (RSRE), will be the first. In parallel with the development of a U.K. EADTB node, RSRE will enhance its existing Air Defense Test Bed. This cooperative program, which was established between the USASDC (the executing agent) and RSRE through a Letter of Offer and Acceptance, coordinates these independent U.S. and U.K. projects. Each project will benefit from access to more powerful, flexible, and cost-effective common-user facilities, and each will gain insight and experience in working together. In this cooperative effort, the U.S. share of the cost is 42 percent, and the U.K. share is 58 percent.

8.5 Foreign Technology Support

This project supports a variety of cooperative programs. A program with Israel will develop and demonstrate hypervelocity gun technology that will increase gun efficiency and projectile velocity while reducing the power requirement and weight. It also will demonstrate innovative concepts, such as a hybrid process of combining chemical propulsion with plasma injection and a traveling charge, equivalent to the addition of propellant and subsequent ignition along the length of the barrel. After engineering evaluations, the most promising technology will undergo more detailed analyses/experiments. Initial firing of the gun has been successfully completed. In addition, SDIO experiments will continue the evaluation of allied and U.S. systems, subsystems, and components to determine the potential these items might have with respect to TMD. Items for testing might include kill mechanisms, sensors, and battle management, command, control, and communications. The experiments will provide data to aid in development of a TMD capability.

Chapter 9

SDI Program Management

Chapter 9
SDI Program Management

When the SDI Program formally entered the defense acquisition process in June 1987, it was required to meet all of the major Department of Defense (DOD) acquisition milestones, including continuous extensive review by the Defense Acquisition Executive (DAE) and his review mechanism, the Defense Acquisition Board (DAB). In July 1989, after a period of extensive review and assessment, and in order to meet attendant technical and management integration challenges and reduced funding levels, the Strategic Defense Initiative Organization (SDIO) Director implemented an organizational realignment to better enable the SDIO to meet SDI Program objectives in the 1990s and beyond. To this end, SDIO has taken steps to refine its management techniques to position it to guide and direct the Program effectively and to enhance coordination and cooperation within SDIO and with external organizations. The overall management approach focuses on centralized planning and decentralized execution of Program tasks to establish clear executing agency accountability in the pursuit of the Program goals.

9.1 Management Approach

The key to a successful integrated SDI Program is strong central directive authority vested in the SDIO Director and well-defined procedures for general coordination and interaction between SDIO and the SDI Program's executing agencies. The Director has been given the authority and responsibility, and is accountable to the Deputy Secretary of Defense, to successfully execute a robust research program balanced with system development activities. The Director has also been designated the SDI Acquisition Executive (SDIAE). The SDI Program authority and the programmatic decision process flow from the DAE (Office of the Secretary of Defense, Under Secretary of Defense for Acquisition), to the SDIAE, and to the Service Acquisition Executives (SAEs). All Program activity is under the broad direction and control of the Director, who will direct the use, as appropriate, of existing management and technical expertise of the SDIO, the Military Services, and other participating agencies in the integration of SDI Program activities.

While the Program is centrally managed and integrated by SDIO, execution of the individual element technology and development efforts is delegated to the Services and other participating agencies. Therefore, effective communications and teamwork among all Program participants—SDIO, the Services, the Joint Staff, U.S. Space Command (USSPACECOM) as the user, and other executing agencies—are essential. The Director's centralized oversight of all SDI Program activities and resources and his direct interaction with the SAEs ensure that the Program is focused and integrated at all levels. A systems engineering and integration contractor is supporting the SDIO Deputy for Engineering and the Services in accomplishing Phase I Strategic Defense System (SDS)-related activities.

To ensure that SDIO maintains the capability to manage and integrate the full scope of the Program, the following management guidelines and activities have been implemented:

- An acquisition strategy for the SDS that will follow a phased development approach
- Realignment of internal SDIO offices to more effectively support the Director's concept of operations and thereby provide balanced emphasis for system development and technology research, and effective control, coordination, and integration for project execution
- A functional organization that embraces four basic disciplines: (1) systems engineering, (2) project management, (3) technology development, and (4) program operations
- An SDIO Planning and Resources Board and a System Design Board to review all major program and resource issues and provide options and recommendations for the Phase I SDS design, respectively.

In addition, SDIO has written Memorandums of Agreement with the services and with USSPACECOM that outline responsibilities and general coordination and interaction procedures for SDI Program technology research, development, and future use. These responsibilities and procedures will continue to evolve as the Program matures and progresses through the acquisition process.

The Army and Air Force have each designated Program Executive Officers and Program/Project Managers (PMs) to execute the individual element projects to which they have been assigned by SDIO. The Service element PMs plan and execute their designated element projects in consonance with SDIO guidance.

Technical and program direction and funding will continue to cover both system development and the continuing research necessary to carry out service-managed element projects and other agencies' SDI Program activities in accordance with agreements between the Director and the SAEs and the appropriate agency directors.

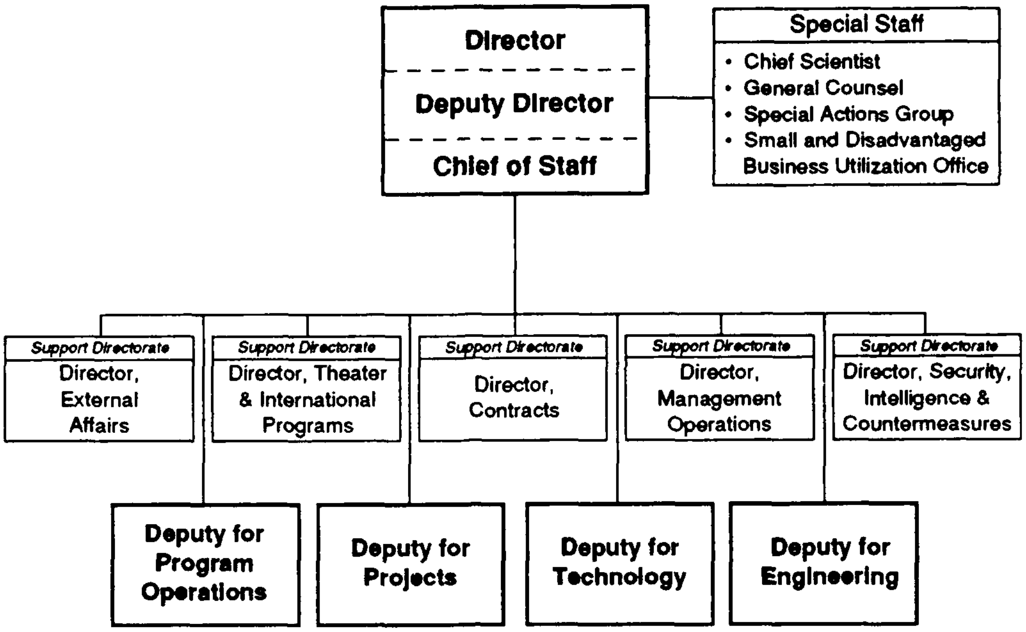
Total Quality Management for all SDS element and technology development programs will be implemented to achieve continuous improvement of the SDS design and development as well as of any future manufacturing processes throughout the acquisition cycle.

9.2 Organizational Structure

The SDIO completed an internal realignment on July 17, 1989 (see Figure 9-1). The principal factor that led to the realignment was the Director's desire to clearly assert SDIO's role as the overall SDI Program integrator and monitor of executing agent activities. To this end, he adjusted the management structure to better execute the organizational interactions necessary to effectively integrate his functional responsibilities and to maximize the effectiveness of available resources, both funding and personnel. In explaining the organizational realignment, the Director stated:

> A major objective of the realignment is to establish an organizational structure that provides a balanced emphasis (of activities) for system development and technology research, and effective control and coordination for project management. These key activities can be categorized as systems engineering, technology development, project management, and program operations.

Figure 9-1
Strategic Defense Initiative Organization



The realignment included the identification of special staff offices and increased Deputates from two to four. The new organizational structure is designed to assure the integration, review, and coordination of architectural studies, element concepts, and technology requirements among the executing agents to achieve an affordable overall SDS design. During the implementation phase, the new organization structure assures the constant participation required by all parties to balance technical trade-offs and programmatic guidance.

The realignment does not suggest a change to either the immediate or the long-term objectives of SDI. It continues to recognize the special role that the Command Center Element (CCE) and related command and control functions play in the overall system development process. Because the CCE is expected to link all the SDS elements into a cohesive ballistic missile defense, the Director has assigned the Deputy for Engineering the responsibility for this element and overall systems integration. The Deputy for Engineering will maintain direct control over the development of the Phase I CCE and command and control concepts; support the conduct of related battle management command, control, and communications technology research; and direct overall systems integration activities.

9.3 Programmatic and Financial Management

This section discusses Program Management Agreements (PMAs), information resources management (IRM), the Planning and Resource Board (PRB), and the Defense Acquisition Review Team (DART).

To achieve centralized programming, budgeting, and execution of the SDI Program, PMAs are used to provide formal guidance and directions to the Services and other agencies. PMAs support the monitoring of program execution by providing information on approved research efforts. Development of PMAs is a coordinated effort between the SDIO project integrator and the Service or agency program manager.

Once a PMA has been defined, staffed, and determined to be within SDI Program resource constraints, it is signed by a senior executing agent official and the Director, SDIO. The approved PMA becomes an agreement for program execution. The PMAs have been and continue to be evaluated. They are evaluated when the respective programs are audited by either the General Accounting Office, DOD, the Inspector General (IG), the Military Service audit teams (e.g., Army Audit Agency), or the Military Service IG and internal review teams. In addition, SDIO holds semiannual budget execution reviews where selected PMAs are reviewed to evaluate execution.

The SDIO has established a full IRM program. Work associated with this program includes the development of a 5-year automated information systems plan, the development of a management information system, the establishment of SDI-wide IRM procedures, and the review and coordination of SDI-wide efforts associated with the development of computer and telecommunication systems. The results of these activities will significantly enhance the ability of the SDIO and its executing agents to effectively manage the many projects associated with the SDI Program.

The PRB reviews proposed program and budget guidance, SDI programming and budgeting actions, and fiscal performance during the year, and makes recommendations to the Director on issues related to these activities. The PRB is chaired by the Deputy Director, SDIO. Primary members include the Chief of Staff, the Chief Scientist, and the Deputies for Technology, Projects, Engineering, and Program Operations. Other SDIO offices may provide representatives to act in an advisory capacity. The services and other agencies may send representatives to PRB meetings at the request of the chairman.

The DART was established in September 1987 to guide and oversee planning and preparation for the first annual DAB review. On February 29, 1988, the Director established the DART as a permanent SDIO entity under the direction of the then Deputy for Programs and Systems. At the same time, the DART's role was expanded to provide a central mechanism to integrate all SDIO directorates in accomplishing short-notice tasks, special projects, and information dissemination/coordination related to the SDI Program. On March 10, 1989, the SDIO Director reaffirmed the expanded role for the DART, which now also functions as SDIO's primary coordinating body with the Office of the Secretary of Defense staff. The DART continues to guide and oversee planning and preparation for the annual DAB reviews, which require the participation and cooperation of the Joint Staff, DOD Staff, Services, and USSPACECOM. The DART is now under the Deputy for Programs Operations.

9.4 Internal Management Controls

The DOD Inspector General evaluated the SDIO Internal Management Control program in July and August 1988 and concluded that the SDIO system complied with the Federal Manager's Financial Integrity Act. Since that time, SDIO has continued to strengthen its internal control program. The key elements of this program are senior management participation and the evaluation and development of more detailed policy and procedures.

Appendix A

Soviet Countermeasures

Appendix A
Soviet Countermeasures

This appendix discusses possible Soviet countermeasures to the SDI Program and factors affecting the Soviet response to the SDI.

The Soviets clearly perceive SDI as a technical, political, economic, and military threat. Soviet responses will primarily be shaped by their perception of how the SDI Program will affect their strategies and programs. Those perceptions will be driven, in large part, by their understanding of the scope and nature of SDI, the political support sustaining it, and the likelihood of its success. Soviet technological and economic strengths and weaknesses will shape the difficult trade-offs among their many potential responses to the SDI Program.

Given the range and uncertainty of potential Soviet responses to a future U.S. SDS, the Strategic Defense Initiative Organization (SDIO) maintains close ties with the U.S. intelligence community to define more accurately Soviet capabilities and potential reactions. In addition, SDIO maintains a Red-Blue Team effort wherein one group of innovative thinkers adopts a Soviet mind-set (Red Team) and develops excursions to the baseline intelligence community estimates; another group (Blue Team) develops potential U.S. counters. SDIO's close relationship with the intelligence community and its Red-Blue Team efforts enable it to maintain a balanced program with prudent hedges against realistic Soviet capabilities.

Soviet Capabilities

Potential Soviet countermeasures to SDS include modifications to the offensive threat, such as decoys and replicas that attempt to confuse and overwhelm SDS elements; defense suppression/antisatellite (ASAT) techniques, such as orbital and direct-ascent interceptors; and advanced technologies, such as ground- and space-based directed energy weapons and kinetic energy weapons.

The Soviets continue to maintain their co-orbital ASAT interceptor, the world's only operational ASAT system; it is a distinct threat to low-altitude satellites. Other Soviet systems have ASAT capabilities. Although not judged to be operational ASAT systems, the Galosh antiballistic missile (ABM) interceptors have an inherent capability against low-altitude satellites. Soviet ground-based lasers could possibly damage some sensors on some U.S. satellites. The Soviets are also technically capable of conducting electronic warfare against space systems.

The USSR's military laser program involves more than 10,000 scientists and engineers as well as more than a half-dozen major research and development facilities and test ranges. Soviet scientists have been exploring several types of lasers such as gas-dynamic, electric discharge, chemical, x-ray, free electron, excimer, and argon-ion that may prove useful for weapons applications.

Since the late 1960s, the Soviets have been exploring the feasibility of using particle beams for a space-based weapons system. Also the USSR is researching the use of strong radio-frequency (high-power microwave) signals that have the potential to interfere with or destroy critical electronic components of satellites.

SDIO Countermeasures Program

The purpose of the SDIO Countermeasures Project is to provide technical evaluations of potential Soviet countermeasures and to ensure that counter-countermeasures are considered by SDI system designers and technology developers. Red-Blue countermeasure analyses focused primarily on boost, post-boost, and midcourse countermeasure issues in FY 1989 and early FY 1990. The analyses examined the technical credibility, effectiveness, cost, and possible deployment schedules for various concepts. Simulations were conducted to assess the performance of defensive systems against candidate offensive and defense suppression threats. In the past year, major technical Red-Blue Team analyses were conducted to assess technical countermeasures to the Phase I architecture and Brilliant Pebbles (BP).

Phase I Architecture Red-Blue Analysis

This effort examined the impact of countermeasures as defined by SDIO following the fall 1988 Defense Acquisition Board review. The Red Team defined a suite of countermeasures, while the Blue Team assessed impacts of the countermeasures on the SDS and proposed appropriate system modifications that could restore the effectiveness of a strategic defense system.

Brilliant Pebbles Red-Blue Analysis

The initial Red-Blue analysis evaluated the BP concept and defined potential countermeasures to it. While no "showstopping" countermeasures were identified, further analyses must be accomplished to measure the level of impact of those initially considered stressing to the architecture. Additional Red-Blue interactions are planned to examine countermeasures to modified BP architectures.

Countermeasures Verification

The countermeasures verification effort seeks to determine through tests the effectiveness of potentially stressing countermeasures. Many of the countermeasures identified by Red-Blue Team analyses require testing. The major thrusts of the countermeasures verification effort include laboratory and flight tests. Two recent experiments are the Cloud experiment and a second Countermeasures Project test.

Cloud Experiment

Many concepts have been studied to define techniques for masking signatures of objects in space. The purpose of this experiment was to determine the signature of particle clouds in space. The experiment was launched from Kauai Test Facility, Hawaii, on November 1, 1988, using a Terrier Tomahawk sounding rocket. Data were collected by still cameras and the Air Force Maui Optical Station (AMOS).

Second Countermeasures Project Test

The second Countermeasures Project test investigated the deployment feasibility and performance of decoys. Other objectives included demonstrating new telemetry and deployment hardware. The test platform was launched on September 26, 1989 from Vandenberg AFB, California, with impact at Kwajalein Atoll. Western Test Range radars, AMOS systems, and an on-board camera were used to measure the characteristics of the RV as it neared Kwajalein. The demonstration of deployment hardware and telemetry systems was successful. The experiment's data analysis should be completed in April 1990.

Appendix B

SDI and the Allies

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This appendix responds to the Congressional requirement to include in the annual report on the Strategic Defense Initiative (SDI) the status of consultations with other member nations of the North Atlantic Treaty Organization (NATO), Japan, and other appropriate allies concerning research being conducted in the Strategic Defense Initiative Program.

Overview

When President Reagan announced the SDI in a March 1983 speech, he emphasized that the program would be designed to enhance allied as well as U.S. security. In accordance with that mandate, the Strategic Defense Initiative Organization (SDIO) is examining technologies and concepts for defense against all ballistic missiles, regardless of their range or armament. The program strengthens the U.S. commitment to the defense of NATO and other allies and enhances our common security.

The U.S. government has been engaged in close and continuing consultations with its allies on the SDI since its inception. The United States also consults with the allies on exchanges with the USSR at the Defense and Space Talks in Geneva and other high-level meetings that bear on the SDI Program. Those consultations will continue. Furthermore, the United States will consult closely with its allies regarding any future decision to deploy defenses against ballistic missiles.

Contacts with the allies on the SDI go well beyond consultation. In March 1985, the United States invited its allies to participate directly in SDI research. Pursuant to that invitation, several Memorandums of Understanding (MOUs) on participation in SDI research have been signed with the allies and numerous contracts and subcontracts have now been signed with foreign companies and laboratories. Approximately 102 allied firms and research institutions are performing or have performed SDI research. The SDIO has also recently signed several cost-sharing, project-specific cooperative research commitments with the allies.

Consultations With Allies on the SDI

Consultations with friends and allies on the SDI broadened and deepened throughout 1989. As in past years, such discussions are a regular feature of numerous bilateral and multilateral meetings with allied officials at all levels, both in Washington and abroad.

President Bush, Secretary of Defense Cheney, and Secretary of State Baker have discussed the Program in many of their bilateral meetings on security matters with their allied counterparts. Secretaries Cheney and Baker also consulted with NATO defense and foreign ministers on the SDI and SDI-related arms control issues at the ministerial meetings of the NATO Nuclear Planning Group (NPG) (April and October 1989) and the North Atlantic Council (June and December 1989). Lieutenant General Monahan, USAF, Director of the SDIO, provided the NPG Ministers with a program status report during their October 1989 meeting.

In addition, U.S. officials consulted extensively with allied leaders, both bilaterally and at NATO, on the results of high-level meetings with the Soviet Union at

which SDI was discussed. For example, this was done immediately following each round of the Defense and Space Talks in Geneva. Furthermore, senior government and industry personnel from several allied countries have visited the United States for detailed technical discussions and updates on the SDI Program. The SDI Program is sponsoring periodic advance planning briefings to acquaint government and industry representatives from selected allied nations, as well as U.S. industry, with SDI programs, initiatives, missions, and future acquisition plans. The SDI also sponsors annual, classified, and multinational conferences on theater ballistic missile defense technology.

Allied Participation in SDI Research

Allied participation in SDI research—increasingly rich in technical merit through rigorous competition—is of great benefit to the United States as well as to the participating nations. Allied participation contributes to the timely attainment of SDI objectives with work of the highest quality performed at the lowest possible cost.

The United States has signed MOUs on participation in SDI research with the governments of the United Kingdom (December 1985), Federal Republic of Germany (March 1986), Israel (May 1986), Italy (September 1986), and Japan (July 1987). The MOUs are not related to specific projects; they are designed to facilitate allied participation in SDI research insofar as that is permitted under U.S. laws, regulations, and international obligations (including the Antiballistic Missile Treaty). While such an MOU is helpful, it is not mandatory for participation. Companies in countries that have not signed an MOU have successfully competed for contracts.

All SDI contracts are awarded strictly on the basis of technical merit and cost, in accordance with the procurement practices mandated by the Congress. Several such provisions apply to the awarding of SDI contracts to foreign firms. The Bayh Amendment to the FY 1973 Department of Defense Appropriations Act provides that no DOD R&D contracts may be awarded to foreign firms if a U.S. entity is equally competent to carry out the work and is willing to do so at lower cost. The Defense Appropriations Acts for Fiscal Years 1986 and 1987 prohibited any set-asides of funds for SDI research contracts awarded to foreign firms and stated that U.S. firms should receive SDI contracts unless such awards would be likely to degrade research results.

In 1987, the Congress enacted additional legislation (Section 222, National Defense Authorization Act for Fiscal Years 1988 and 1989) regarding allied participation in the SDI Program. The new legislation prohibits the award of new SDI contracts to allied entities unless certain conditions are satisfied. Such provisions shall not apply to the award of subcontracts. In FY 1989 nine contracts were awarded to foreign entities under Public Law 100-180, Section 222. Three of these contracts were awarded to foreign firms because "the contract is exclusively for research, development, test, and evaluation in connection with antitactical ballistic missile systems (ATBMs)." Three contracts were awarded because a "foreign government or foreign firm agreed to share a substantial portion of the total contract cost." These contracts are with an Israeli company for the Israeli Test Bed (ITB), the U.K. Ministry of Defence (MOD) for artificial intelligence, and the U.K. MOD for development of a lab demonstrator for naval command and control and SDI theater missile defense applications. The remaining three contracts were awarded under provisions of subsection (b) of Section 222.

Long-standing laws and policies governing rights to research results developed under U.S. contracts ensure that the U.S. technology base receives the benefits of all SDI research, whether performed by a domestic or foreign contractor. In accordance with these laws and policies, the U.S. government will receive rights to use the technology developed under SDI contracts. Contractor rights to use the result of their SDI research depend on security considerations and the specific conditions of each contract. These ground rules for cooperation are fully reflected in each of the MOUs and Memorandums of Agreement (MOAs) the United States has signed on participation in SDI research.

A summary of major SDI contracts and subcontracts awarded to allied firms and research establishments between October 1985 and October 1989 is as follows:

- United Kingdom: $73.04 million. Optical and electron computing, ion sources for particle beams, electromagnetic rail gun technology, optical logic arrays, meteorological environment, test bed, and theater defense architecture.

- Federal Republic of Germany: $70.25 million. Pointing and tracking, optics, free-electron laser technology, lethality and target hardening, electron laser technology, and theater defense architecture.

- Israel: $184.48 million. Electrical and chemical propulsion, short-wave chemical lasers, theater defense architecture, the Arrow experiment, and ITB.

- Italy: $15.17 million. Cryogenic induction, millimeter-wave radar seeker, theater defense architecture, and smart electro-optical sensor techniques.

- Japan: $3.01 million. Western Pacific theater architecture study.

- France: $12.41 million. Sensors and theater defense architecture.

- Canada: $3.48 million. Power system materials, particle accelerators, platforms, and theater defense architecture.

- Belgium: $297,000. Theater defense architecture, laser algorithms.

- Netherlands: $12.04 million. Theater defense architecture and electromagnetic launcher technology.

- Denmark: $28,000. Metrology of magnetic optics.

Cooperative Programs With Allies in the SDI Program

Since the inception of allied participation, SDIO envisioned cooperative programs as one modality for research efforts. The Congress also encouraged cooperation, providing specific direction in the early years of the program. Section 212 of the FY 1987 National Defense Authorization Act provided a $50-million ceiling on the obligation of FY 1987 SDI funds "for the joint development, on a matching-fund basis, of an antitactical ballistic missile (ATBM) system for deployment with NATO allies and other countries that the United States has invited to participate in the SDI Program." Section 217 of the National Defense Authorization Act for Fiscal Years 1988 and 1989

directed that, of the funds appropriated for the SDI Program in FY 1988, "$50 million shall be made available for experiments, demonstration projects, and development relating to ATBM systems. Such projects shall be conducted on a matching-fund cooperative program basis with United States allies that have signed MOUs for participation in the SDI Program." Having provided these early catalysts, Congress did not include any similar language in FY 1990.

The following programs illustrate cooperative research arrangements with allies and their industries:

- The cooperative research on electromagnetic launcher technologies with the Netherlands Organization for Applied Scientific Research, which was discussed in the FY 1988 Report to the Congress on SDI, is proceeding as scheduled. The electromagnetic launcher leased to the Dutch has been assembled and fired in the Netherlands. In FY 1989, SDI and the Dutch completed system characterization and commenced joint testing.

- In June 1988, the SDIO and the Israeli MOD concluded an MOA for a cooperative SDI research project on the Arrow ATBM experiment. This experiment, designed to demonstrate the capability to intercept a surrogate tactical ballistic missile, will be conducted at an Israeli test range.

- In March 1989, the SDIO and the Israeli MOD concluded an MOA for a cooperative program to develop the ITB, an advanced computer simulation/emulation facility to be built in Israel for use in evaluating Middle East missile defense concepts and designs.

- In November 1988, SDIO signed a contract with a Japanese firm to analyze a theater missile defense architecture for the Western Pacific theater. The firm will assess the unique requirements associated with the defense of U.S. and allied assets in the Western Pacific against attack by medium- and short-range ballistic missiles. The firm will also supplement the basic contract with additional study tasks accomplished at its own expense.

- In May 1989, SDIO signed a cost-sharing contract for the development of a low-cost hypervelocity gun with an Israeli government research facility. The project will develop a gun capable of accelerating projectiles to velocities of 2.5-4.0 km/sec using electrothermal, electromagnetic, or other advanced concepts; examine the feasibility of launching small pellets or plasma particles at extremely high velocities for use in midcourse balloon and decoy discrimination; perform barrel and armature material research; and resolve other technical issues regarding hypervelocity gun technology.

- In January 1989, SDIO and the U.K. MOD signed a cooperative agreement to develop a prototype artificial intelligence framework. The framework is based on the principle of comparing *a priori* information about offensive missile objects to real-time sensor data. The prototype is based on a blackboard architecture where signal processing, clustering, and raid assessment rules are partitioned. Tasking and data sharing are managed adaptively by the framework control module to maximize the timeliness and accuracy of the discrimination process. This was originally a 1-year effort

to show proof of concept. Because this approach was successfully demonstrated the agreement is being extended for an additional year.

- SDIO and the U.K. MOD signed a cooperative agreement in April 1989 for the development of a Knowledge-Based System (KBS) Data Fusion Demonstrator. The effort will develop battle management algorithms based on KBSs for fusing information gathered by disparate types of sensors, an area identified by the European BM/C[3] Architecture Concept Definition Study as warranting further emphasis. The program involves the development of a data fusion demonstrator and a research effort in KBSs.

- The United States, under a cost-sharing Letter of Offer and Acceptance with the U.K. MOD, is undertaking a joint cooperative program, known as the Extended Air Defense Test Bed (EADTB). The EADTB is designed to provide support for extended air defense planning, concept analysis, doctrine development, and battle plan development. The program is currently in the design and implementation phase.

- In January 1990, SDIO signed an MOA with the French Ministry of Defense regarding free electron laser research. Under this 5-year agreement information will be exchanged and cooperative research projects will be developed with the goal of reducing both the cost and schedule of the participants' research programs. Discussions are now underway to implement this MOA.

The SDI Program is engaged in exploratory discussions with allies to determine other areas of mutual research interest to be pursued in similar types of cooperative arrangements.

Defense Against Shorter-Range Ballistic Missiles

The United States, NATO, Israel, and Japan are actively addressing the need for ATBM defenses in light of the tactical missile threat faced by our allies and U.S. forces overseas. NATO is engaged in a number of studies to further define the threat and to determine what measures should be undertaken to meet that threat.

SDIO allocated $109.3 million in FY 1989 for research on theater missile defense concepts and technologies. Such ATBM efforts, particularly via cooperative arrangements, have been supported by the Congress.

In its ATBM efforts, SDIO has worked very closely with the U.S. Army. The U.S. Army, which has been designated as the lead service for DOD's overall ATBM program, continues to organize overall support for the ATBM. At the same time, the SDI continues to examine technologies and concepts for active defenses against ballistic missiles of all ranges and armaments, including those shorter-range systems that directly threaten our friends and allies and are not proscribed by the Intermediate Nuclear Forces Treaty. The Army's Strategic Defense Command has been designated as the SDI executive agent to manage this theater defense portion of the SDI Program. The advances in technology achieved in the SDI Program will be made available to the Army's ATBM program through the SDC.

SDI research awards for theater defense have included architecture studies—performed by the governments of the United Kingdom and Israel and by several multinational contractor teams—as well as specific technology programs and

experiments. The theater architecture studies, together with follow-on activities to be performed in theater test beds, will contribute importantly to our collective thinking on the vital issue of ensuring NATO's and other allies' security against the threat of Soviet ballistic missiles and a panoply of third world shorter-range ballistic missiles over the near and longer term.

Summary of Allied Participation and Cooperation

Allied scientific excellence and technical capabilities have been and continue to be demonstrated through contractual efforts and cooperative research projects. Their technical contributions relate to both strategic ballistic missile and theater missile defenses.

There have been many notable achievements. During the past year, for instance, Culham Laboratories in the United Kingdom provided the continuous ion source for the Beam Experiment Aboard Rocket, a neutral particle beam experiment that was flown in July 1989. In another case, SDIO will get to use the West German-built Shuttle Pallet Satellite (SPAS) as a carrier for the infrared sensor in the so-called Infrared Background Signature Survey (IBSS), which will measure, inter alia, orbiter plumes, the earth limb, the earth background, and the orbiter environment. The SPAS vehicle, designed for payload flexibility, high strength, and light weight, has flown successfully two previous missions and is manifested for IBSS on a Shuttle flight scheduled for January 1991.

Currently, trends in allied involvement in the SDI Program are toward more theater missile defense-related activities, test bed and technology experiments, and other cooperative activities of mutual interest. The continued participation and cooperation of the allies in the SDI Program will promote greater scientific understanding and technological mastery of the ballistic missile defense problem. Through these multinational efforts, SDIO's theater and strategic missile defense technologies will continue to advance. Additionally, such participation and cooperation will provide a sound basis for U.S. and allied leaders to make informed decisions about their common security.

Appendix C

SDI Compliance With the ABM Treaty

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This appendix addresses the portion of Section 224 of the November 7, 1989, Conference Report authorizing appropriations for FY 1990 for military activities of the Department of Defense, which requests "A statement of the compliance of the planned SDI development and testing programs with existing arms control agreements, including the 1972 Anti-Ballistic Missile Treaty."

Introduction

The 1972 ABM Treaty addresses the development, testing, and deployment of different types of ABM systems and components. It should be noted that nowhere does the ABM Treaty use the word "research." Neither the United States nor the Soviet delegation to the SALT I negotiations chose to place limitations on research, and the ABM Treaty makes no attempt to do so. The United States made it clear during the ABM Treaty negotiations that development commences with the initiation of field testing of a prototype ABM system or component. The United States had traditionally distinguished "research" from "development" as outlined by then United States delegate Dr. Harold Brown in a 1971 statement to the Soviet SALT I delegation. Research includes, but is not limited to, conceptual design and laboratory testing. Development follows research and precedes full-scale testing of systems and components designed for actual deployment. Development of a weapon system is usually associated with the construction and field testing of one or more prototypes of the system or its major components. However, the construction of a prototype cannot necessarily be verified by national technical means (NTM) of verification. Therefore, in large part because of these verification difficulties, the ABM Treaty prohibition on the development of sea-, air-, space-, or mobile land-based ABM systems, or components for such systems, applies when a prototype of such a system or its components enters the field testing stage.

The ABM Treaty regulates the development, testing, and deployment of ABM systems whose components were defined in the 1972 Treaty as consisting of ABM interceptor missiles, ABM launchers, and ABM radars. Systems and components based on other physical principles (OPP) are addressed only in Agreed Statement D to the Treaty as "ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars." In order to fulfill the Treaty's basic obligation not to deploy ABM systems or components except as provided in Article III, this agreed statement prohibits the deployment of systems or components based on OPP, but does not proscribe the development and testing of such systems, regardless of basing mode. The SDI Program will continue to be conducted in a manner that fully complies with all United States obligations under the ABM Treaty.

Research and certain development and testing of defensive systems are not only permitted by the ABM Treaty, but were anticipated at the time the Treaty was negotiated and signed. Both the United States and the USSR supported this position in testimony to their respective legislative bodies. When the Treaty was before the United States Senate for advice and consent to ratification, then Defense Secretary Melvin Laird advocated, in his testimony, that the United States "vigorously pursue a

comprehensive ABM technology program." In a statement before the Presidium of the Supreme Soviet, Marshall Grechko said the ABM Treaty "places no limitations whatsoever on the conducting of research and experimental work directed toward solving the problem of defending the country from nuclear missile strikes."

Existing Compliance Process for SDI

DOD has in place an effective compliance process (established in 1972, after the signing of the SALT I agreements) under which key offices in DOD are responsible for overseeing SDI compliance with all United States arms control commitments. Under this process the SDI Organization (SDIO) and armed services ensure that the implementing program offices adhere to DOD compliance directives and seek guidance from offices charged with oversight responsibility.

Specific responsibilities are assigned by DOD Directive 5100.70, 9 January 1973, Implementation of SAL Agreements. The Under Secretary of Defense for Acquisition, USD(A), ensures that all DOD programs are in compliance with United States strategic arms control obligations. The Service secretaries, the Chairman of the Joint Chiefs of Staff (JCS), and agency directors ensure the internal compliance of their respective organizations. The DOD General Counsel provides advice and assistance with respect to the implementation of the compliance process and interpretation of arms control agreements.

DOD Instruction S-5100.72 establishes general instructions, guidelines, and procedures for ensuring the continued compliance of all DOD programs with existing arms control agreements. Under these procedures, questions of interpretation of specific agreements are to be referred to the USD(A) for resolution on a case-by-case basis. No project or program which reasonably raises a compliance issue can enter into the testing, prototype construction, or deployment phase without prior clearance from the USD(A). If such a compliance issue is in doubt, USD(A) approval shall be sought. In consultation with the DOD General Counsel, Office of the Assistant Secretary of Defense for International Security Policy, and the JCS, the USD(A) applies the provisions of the agreements, as appropriate. Military departments and DOD agencies, including SDIO, certify internal compliance quarterly and establish internal procedures and offices to monitor and ensure internal compliance.

In 1985, the United States began discussions with allied governments regarding technical cooperation on SDI research. To date, the United States has concluded bilateral SDI research Memorandums of Understanding with the United Kingdom, the Federal Republic of Germany, Israel, Italy, and Japan. All such agreements will be implemented in a manner consistent with United States international obligations, including the ABM Treaty. The United States has established guidelines to ensure that all exchanges of data and research activities are conducted in full compliance with the ABM Treaty obligations not to transfer to other states ABM systems or components limited by the Treaty, nor to provide technical descriptions or blueprints specially worked out for the construction of such systems or components.

SDI Experiments

All SDI field tests must be approved for ABM Treaty compliance through the DOD compliance process. The following major programs and experiments, all of which involve field testing, have been approved: the Delta Star Experiment (on orbit, launched March 1989); the Laser Atmospheric Compensation Experiment (LACE) and

Relay Mirror Experiment (RME) (on orbit, launched February 1990); the Kinetic Kill Vehicle Integrated Technology Experiment (KITE) flights in the High Endoatmospheric Defense Interceptor (HEDI) program; the Airborne Surveillance Testbed (AST), a revision of the Airborne Optical Adjunct Program; the Ground-Based Interceptor (GBI), formerly the Exoatmospheric Reentry Vehicle Interceptor Subsystem (ERIS) flight experiments; the Arrow antitactical missile flight experiments; and the Lightweight Exoatmospheric Projectile (LEAP) flight experiments.

The following major programs and experiments have been approved for later years, subject, in some cases, to review of more completely defined experiments: the Extended Range Interceptor (ERINT) program flight experiments are under review; the Starlab tracking and pointing experiments; the Midcourse Space Experiment (MSX); the Ground-Based Radar Experiment (GBR-X); HEDI; the Ground-Based Free Electron Laser (GBFEL); the Zenith Star space-based laser experiment; the Hypervelocity Gun (HVG); and the Space-Based Surveillance and Tracking System (SSTS).

The Boost Surveillance and Tracking System (BSTS) has been reviewed and guidance issued for the construction and deployment of Treaty-compliant satellites for the Tactical Warning/Attack Assessment mission.

Brilliant Pebbles ground-based testing has been approved through flight number 8.

In addition, the following data collection activities, which have not been considered as major, continue to be approved: the Three Color Experiment (TCE)/Visible Ultraviolet Experiment (VUE); the Optical Airborne Measurement Program (OAMP); the Sounding Rocket Measurement Program (SRMP); Red Gemini III; the Infrared Background Signature Survey (IBSS) experiment; the Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS) 1A experiment; Excede III; Spirit II; Space Power Experiment Aboard Rockets (SPEAR) II; Zodiac Beauchamp; and the Firefly/Firebird experiments.

The following programs have approved activities that are not considered to be in field testing: Alpha/LAMP/LODE, the Ground-Based Surveillance and Tracking System (GSTS), and the Space-Based Interceptor (SBI). Also, the National Test Facility has been determined to be compliant with the ABM Treaty.

Currently, no experiment has been approved which would not fall within the categories used in Appendix D to the 1987 Report to Congress on the SDI. Changes to previously approved experiments require compliance review.

Appendix D

SDI Technology and Other Defensive Missions

Appendix D
SDI Technology and Other Defensive Missions

This appendix responds to parts (b)(9) and (b)(10) of Section 224 of the November 7, 1989 Conference Report authorizing appropriations for FY 1990. Those parts request details on what SDI technologies can be developed or deployed within the next 5 to 10 years to defend against significant military threats and help accomplish critical military missions. The status of the SDI technologies referred to in this Appendix is addressed in the body of this report.

SDI Research and Its Use in Other Defensive Missions

In late 1987, the Department of Defense (DOD) Defense Resources Board (DRB) requested that a study be conducted to evaluate the potential use of SDI technology in other defense-related research and development efforts as recommended by the Director, Strategic Defense Initiative Organization (SDIO). As a result of this study, the DRB supported the establishment of a Joint SDI Defense Technology Applications Initiative (JDAI) panel as a vehicle for sharing SDI technology with other DOD agencies. In December 1987, the Deputy Secretary of Defense directed establishment of the JDAI panel.

The JDAI panel has examined a number of defense programs in its efforts to identify where SDI-developed technologies can be shared to help meet the operational requirements of ongoing DOD research and development work. DOD programs being examined include the Air Defense Initiative (ADI), the Balanced Technology Initiative (BTI), strategic force modernization, space systems, and science and technology programs. Other programs the JDAI panel is reviewing in its evaluation process include those focusing on the hardening and survivability of conventional defense systems; communication and information technologies; and test facilities, resources, and instrumentation.

As part of JDAI panel activities, a number of pilot projects have been started to identify and incorporate SDI technologies into research and development activities undertaken by the services and the Defense Advanced Research Projects Agency (DARPA). The results of this work are summarized in Figure D-1.

Air Defense

The air defense mission encompasses surveillance, warning, interception, and identification or negation of unknown aircraft that penetrate the air defense identification zone. Systems that contribute to that mission in the continental United States include the Joint Surveillance System network of Air Force and Federal Aviation Administration radars, the North American Warning System of radars across Alaska and Canada, Airborne Warning and Control System (AWACS) aircraft, and those fighter-interceptors on continuous alert. These systems will be augmented by the Over-the-Horizon Backscatter (OTH-B) radar network, which is scheduled to be operational in the early 1990s. The technical promise of SDI could significantly improve air defense mission efficiency and effectiveness, especially against future threats.

Tactical air defense in a theater of operations includes sensors such as the AWACS and mobile ground-based radars. These provide early warning and engagement control of Air Force air defense and Army antiaircraft surface-to-air missile

Figure D-1
Joint SDI-Defense Application Initiative Activities

REQUESTOR	SOURCE	TYPE	RESULTS*	REMARKS
Army	Future Army weapon systems and associated technology barriers	Forward Area Air Defense System (FAADS)	200	Provided to Army laboratory command staff
		Advanced Antitank Weapon System—Heavy (AAWS-H)	230	
		Light Helicopter Experimental (LHX) family of helicopters	128	Provided to LHX program manager
Navy	Space warfare and naval air mission requirements	24 generic mission technologies	79	Provided to Navy, Chief of Naval Technology
	Navy Balanced Technology Initiative (BTI)	20 top BTI technologies for FY 1989	99	Provided to Navy BTI manager
	Navy EM catapult program	EM-related technologies	12	Provided to Lakehurst, NJ, program manager
Air Force	Air Force Project Forecast II future system needs	Supersonic vertical/ short takeoff and landing (V/STOL) fighter	219	Provided to Air Force JDAI panel members
		Hypersonic vehicle	460	
		Super Cockpit	140	
	Advanced Tactical Fighter	18 technology areas	301	Provided to SPO
	Strategic offense	BM/C^3, strategic relocatable targets	104	SAC and Joint Strategic Target Planning System (JSTPS) to review
Defense Advanced Research Projects Agency (DARPA)	Balanced technology program	Smart weapons program	43	Provided to DARPA program manager
	Strategic Technologies office	Strategic relocatable targets	58	Provided to appropriate service staffs
Classified	Classified	5 technology areas	122	

* The number of cross-matched SDI technologies that could meet requirements of the DOD program in question.

systems such as the Patriot and Hawk. This leads to a highly decentralized command and control environment that is today constrained by limitations in current Battle Management/Command, Control, and Communications (BM/C^3) systems.

North American air defense assets operate as a system, with one type of surveillance asset compensating for the deficiencies of others. Interceptor aircraft are necessary because fixed surveillance sensors cannot identify all tracks. In some cases, AWACS aircraft and interceptors actually perform surveillance when transient gaps occur in radar coverage. If fixed or aircraft-based sensors had greater capability, interceptors could perform more critical missions. Improvements in sensor range, data processing, and operating efficiency would greatly facilitate the air defense mission.

Because aircraft can be diverted to many possible targets, it is difficult to discern the character of an air-breathing attack. However, broad patterns of mass raids can be revealed if information from multiple sensors can be assimilated simultaneously. Advances in survivable communications and distributed computation could significantly improve raid recognition, attack assessment, and efficient assignment of interceptors.

Theater air defense operations depend on limited sensor and BM/C^3 architectures, which are in turn affected by electronic countermeasures and raid size. The addition of adjunct sensors using a variety of physical principles would ensure sustained operation and preclude being hampered by a simplified development of countermeasures. Robust BM/C^3 and data processing systems are needed to ensure that adequate theater air defense operations are maintained.

The air defense surveillance mission could obtain substantial benefit from a variety of SDI efforts. Space-based sensors could detect aircraft activity and contribute information for attack assessment. SDI electrical power projects could provide long-term energy sources for unattended ground-based radar systems. Battle management and communications systems within the SDI Program could facilitate sensor data fusion and attack assessment. Improvements in aircraft-based compact data processing and sensor operations could greatly enhance airborne surveillance of air-breathing threats. Survivable, high data rate communication systems could help maintain connectivity among the air defense regions and improve the allocation of interceptors and sensors within and among regions. At the global level, SDI computational technologies and simulation display advances could help integrate air-breathing and missile threat information necessary to respond to combined attacks. SDI kinetic energy interceptor technologies may allow more intercepts with fewer aircraft. Sensor, kinetic energy interceptor, and battle management technologies pursued by the SDI Program would all be applicable to the strategic air defense missions.

Theater air defense operations would also benefit from the development of SDI technologies. For example, the extension of air defense systems to a more robust role could be derived from hypervelocity gun, laser, and kinetic-kill vehicle experiments. Early-warning attack assessment functions would benefit from sensor developments. Missile lethality enhancements could be based on improved lethality and vulnerability analyses. Command, control, and data processing could be improved as a result of the software development and signal data processing work being accomplished for the SDI Program.

Maritime Operations

The global maritime operations of U.S. naval units and fleets in peacetime and wartime are critically dependent on surveillance, communications, and the ability to intercept hostile forces beyond the range at which they can actively threaten fleet units. The U.S. Navy is confronted by a Soviet maritime threat of growing size and sophistication, a multidimensional force that possesses demonstrated capability for surveillance, track, and attack from space, air, surface, and subsurface platforms. Existing Navy defenses involve multiple layers and redundant systems, similar to those proposed for a layered strategic defense against ballistic missiles.

Massive raids of Soviet land-based bombers such as the Backfire (with each bomber carrying numbers of sophisticated antiship missiles [ASMs]) present a threat to the surface fleet. Technology spinoffs from the High Endoatmospheric Defense Interceptor project could contribute to the development of a long-range, ship-based missile for intercepting bombers.

The Soviet land-based bomber threat has greatly increased the fleet defensive perimeter, requiring a secure and survivable communications network and advanced

processing capability to exercise command and control over widely distributed ships, aircraft, sensors, and weapons. Spinoffs from advances in communications, multiprocessors, intelligence interfacing, and software, all now under development in the SDI Program to meet the demanding BM/C^3 needs of a global strategic defense system, should greatly benefit fleet operations in both the near and far terms. For example, the battle management software developed to track and intercept thousands of ballistic missiles and reentry vehicles (RVs) should be readily adaptable to the Navy's less stressing requirements to perform similar operations involving fewer seaborne and airborne friendly and hostile objects. Further, SDI software development tools employing artificial intelligence and knowledge-based technology should markedly reduce the cost and time required to develop and manufacture secure and fault-free software for tactical use.

In the longer term, it is expected that the Soviet bomber ASM launch range and jamming capability will increase and that bomber detectability will decrease. The SDI advanced infrared sensor technology, if applied in naval aircraft and air defense missiles, could help fleet defenses keep pace with advances in the bomber threat. Space-based radar, employing major advances in high-frequency and sophisticated signal processing techniques for extending sensor performance, will offer a valuable mix for confronting the Soviets with a multispectral surveillance, tracking, and targeting capability. Spinoffs from hypervelocity gun and laser technology could result in highly effective ship-based weapons for close-in defense. For example, a rapid-fire electromagnetic gun (rail gun) that propels a low-cost guided projectile would be very attractive for defending against Soviet ASMs launched from bombers, ships, or submarines. Applications of SDI laser weapon technology (excimer, free electron, and chemical) could provide the sure quick-kill defense capability needed to counter even the most advanced Soviet ASMs. Advances made in developing high-power microwave technologies for strategic defense have potential application for seaborne tactical weapons in defense against missiles and targeting satellites and, when delivered by missiles and aircraft in the form of a warhead, for suppression of enemy ship- and land-based defensive radars and C^3 systems.

Conventional Forces

For conventional ground force operations in a European general war, the Soviets have deployed a vast array of weapons to provide massive firepower. This array includes tanks, mobile artillery, and armored personnel carriers as well as sophisticated attack helicopters. These weapons are designed to provide the mobility and firepower necessary to overwhelm NATO forces without resorting to nuclear weapons.

As a counter to this Soviet-Warsaw Pact capability, conventional NATO forces require an infusion of new technologies to provide improved capabilities in the areas of firepower, fire control, command and control, communications, and improved power supplies to enhance the mobile operations of advanced weapons.

The SDIO is developing a range of advanced technologies that will be used in developing advanced weapons, support systems, and control systems for conventional forces. For example, lightweight, rapid-fire hypervelocity gun technologies could provide significant improvements anti-armor, antiaircraft, and fleet defense operations. These kinds of systems could be capable of rapid, lethal response to conventional attack, especially when coupled with low-cost guided hypervelocity projectiles. These technologies may provide the synergy needed to develop an effective long-range deterrent to conventional threat systems.

In addition, the development of high-power-density power supplies could provide a significant benefit to the modern conventional force, especially command and control

and support elements. The technical improvements being made in communications, battle management, and resource allocation also are generating greater demands on the design of effective power supply systems that can provide sufficient power with low noise and/or thermal signatures. Lightweight, quiet power systems would contribute to the reduced signature of critical units and thus enhance survivability while meeting power needs.

The ability to engage more than one target at a time is being developed through advances in computer-aided and controlled multitarget fire control systems. This ability would enhance the battle management functions of all forces and enhance their efficiency in the use of resources.

Recent experiments have demonstrated technologies related to hypervelocity weapons development and have demonstrated rapid-fire operations, launch efficiencies, and electronic switch operations.

The SDI Program is pursuing technology for advanced fire control systems to track multiple targets and guide hypervelocity projectiles to targets. Included are lightweight command-guided projectiles. Such projectiles could provide an air defense or anti-armor capability.

In another critical area, the SDI Program is developing technologies to automate the collection, fusion, and processing of massive amounts of intelligence data on a near-real-time basis. The application of expert systems will further facilitate processing the data to allow force structures to be categorized and tracked. These developments can ensure the timeliness and availability of reliable intelligence to keep pace with increased application of heliborne and mobile forces on a battlefield.

Defense Against Tactical Missiles

In 1987 DOD established an inter-service antitactical missile (ATM) program. DOD also established a balanced program of passive measures, active defense, and counterforce options supported by an integrated BM/C^3 system. The Army was designated as the lead service for the ATM program.

Although allied and U.S. Army ATM efforts are separate from the SDI Program, they remain closely coordinated. Furthermore, the United States fully expects that the theater defense technologies and concepts under examination for SDI can make a substantial contribution to defense against tactical missiles. These technologies and concepts are described in Chapter 8 and Appendix B.

Space Defense

The defense of U.S. and allied military space assets is important as long as the Soviets maintain their present co-orbital antisatellite (ASAT) interceptor, develop large-scale directed energy facilities with satellite-attacking capability, and maintain a potential direct-ascent ASAT capability with their deployed ABM interceptor (the nuclear-tipped Galosh).

This section summarizes SDI contributions to provide sufficient warning and tracking information to support satellite survivability as well as a means to defend against, evade, or counter any attack on U.S. military satellites. Particularly relevant are SDI technologies being developed for planned elements (e.g., the Space-Based Surveillance and Tracking System [SSTS], Brilliant Pebbles, and Ground-Based Interceptor) and ground-based laser elements, as well as for responsive or random maneuver, and nuclear, fragment, and laser hardening of space platforms.

The problem of space defense covers the following three areas: space surveillance and tracking, space defense weapons, and space system survivability.

The SDI Program offers a wide range of sensor, radar, and laser technologies to address these areas. Large multispectral focal plane arrays and on-board processing are being developed to work together to provide global coverage and multiple track file maintenance. The technology also may be used on rocket-launched suborbital "probes" for near-term use. Potential space- and ground-based radar technology for space object identification is exemplified by the phased-array Ground-Based Radar Experiment. Short-wavelength lasers have direct potential for tracking and providing rapid images of satellites. In the long term, interceptors or other means of active self-defense are likely to be required (ground-launched interceptors could be used against the co-orbital ASAT).

Another category of space defense technologies involves assuring space system survivability through passive and active countermeasures. The United States has worked on hardening of satellite sensors, structures, and communications systems. Because we must anticipate operations in a future wartime environment with advanced technology defense suppression threats, the SDI Program has invested in survivability technology.

Tactical Warning and Attack Assessment

Tactical warning and attack assessment (TW/AA) provide crucial information that decision makers require to allow them to respond adequately to a ballistic missile attack. TW/AA for strategic defenses will be accomplished using the complete suite of SDI sensors tied into the Command Center/System Operation and Integration Functions. These sensors would complement existing and planned systems. For a multilayered SDS, tactical warning and initial attack assessment would occur in the boost layer. However, later layers—post-boost, midcourse, and terminal—would provide additional sensor information on ballistic missiles or their deployed RVs. This strategic defense system (SDS) surveillance and tracking capability also will enhance our current offensive-based deterrence posture. TW/AA functions are important in all aspects of defensive operations. The sensors being developed in support of SDI goals could provide similar support to conventional defense elements, aid in the proper assessment of information, and help develop appropriate warning. TW/AA functions related to layered missile defense and survivable C^3 are described in the remainder of this section.

Boost Layer. The BSTS will provide the initial TW/AA during the boost stage. The BSTS will detect the launch of ballistic missiles and provide rapid alert, along with the initial count and type of ballistic missiles.

Post-Boost Layer. The post-boost layer occurs as the post-boost vehicle (PBV) leaves the atmosphere and begins deploying its RVs and decoys. During this stage, as the RVs fly their ballistic trajectories, more accurate information about the enemy's targets and intent could be provided for an SDS. This information would be used to prepare subsequent tiers for their defensive roles. This information also would aid in the timely management of offensive strategic forces.

Tracking using the SSTS would begin during this stage. This element would track the cold bodies of the RVs and other objects using advanced passive sensors. Using stereo processing in conjunction with other SSTS satellites, this element would be able to track the cold objects. Information for attack assessment would then be more accurate and would begin to include the number of RVs as well as their target locations.

Midcourse Layer. Objects deployed from the PBV travel ballistically through space. SSTS satellites, which would begin tracking in the post-boost layer, would continue to track reentry clusters. Accurate and timely tracking information would support battle planning. During the midcourse layer, the Ground-Based Surveillance and Tracking System (previously known as the Probe) would start to track the threat cloud.

Terminal Layer. As objects reenter the atmosphere, ground-based terminal radars could provide final attack assessment. This final assessment of the potential RV impact could aid force management.

Survivable C^3. To enable each tier's suite of sensors to provide continuous early-warning and attack assessment, survivable C^3 systems must be built. Systems contemplated by SDI complement C^3 systems already in place and being upgraded by the Air Force. SDI would build on these existing systems to provide continuous C^3 functioning via highly survivable communications links. The SDI Program will provide the technology to implement most of these improvements into existing C^3 systems even if the decision is made not to deploy strategic defenses.

Appendix E

Technology Applications

Appendix E
Technology Applications

In response to congressional and presidential initiatives on competitiveness and technology transfer, the Strategic Defense Initiative Organization (SDIO) established the Office of Technology Applications to develop and implement a technology applications program designed to make SDI technology available to federal agencies, state and local governments, universities, and U.S. business and research interests. SDIO acts as a facilitator by referring those who have a technology requirement to the inventors and developers of SDI-funded technology. This is accomplished by:

- Providing U.S. corporations; small businesses; universities; entrepreneurs; and federal, state, and local government agencies with information about these technologies so that they can contact the technologies' inventors and developers.

- Instituting measures to promote the type of information needed to accelerate the technology spinoff process while preventing the disclosure of sensitive technology data or intellectual property rights.

- Identifying potential private and public sector applications.

Technology Transfer Mechanisms Used by SDIO

The SDIO Office of Technology Applications has developed a technology transfer database referral system, the Technology Application Information System (TAIS), and uses scientific and technical specialists from universities, federal laboratories, private research institutes, corporations, and professional associations to help identify potential spinoffs of SDI technologies. The SDIO TAIS contains more than 1,300 unclassified, nonproprietary abstracts describing SDI technologies in such areas as superconductivity, sensors, lasers, supercomputers, materials, and industrial processes. Entrepreneurs and researchers can access the TAIS by computer modem to identify potential investment opportunities, supplement research and development (R&D) activities, or move an emerging technology from the laboratory to the marketplace. The TAIS also provides other nontechnical information vital to the innovation process such as:

- Business opportunities available through the SDI small business innovation research and innovative science and technology program

- Information on resources and technology transfer services provided by more than 175 federal and 470 state and regional business assistance agencies nationwide

- Information about SDI manufacturing operations development and integration laboratories established to develop domestic manufacturing capabilities that produce advanced components to meet SDI requirements for which industrial capabilities are insufficient or nonexistent.

SDI Spinoffs

SDI-sponsored research is serving as a catalyst for spinoffs in many scientific and technical fields. Representative samples—in areas such as computer, sensor, and semiconductor technologies; material sciences; optics; and medicine—include:

- Lasers in medicine—lasers originally developed with SDI funds are now being used to remove burn and scar tissue from the skin; fragment kidney stones; treat heart disease, cancer, glaucoma, and psoriasis; and remove tattoos without scarring the skin.

- A new generation of optical supercomputers—optical technologies, such as lasers and holograms, are being combined with conventional electronics to produce ultrafast, inexpensive supercomputers that process information 1,000 times faster than current computers.

- Materials for leg braces—SDI-developed carbon material is being tested for use in orthotic braces. Leg braces made with this material are twice as strong and weigh two-thirds less than steel braces.

- A high-resolution, wide-angle lens—a wide-angle lens that produces high-resolution images has been designed for use in real-time satellite systems and distortion-free television cameras.

- An energy-efficient, semiconductor switch—a semiconductor switch has been designed that will have an impact on the next generation of power electronics. Potential applications include electric transportation propulsion, jet engine controls, lighting systems, and variable speed motors. Converting from direct current motor drives using this technology could save as much as 30 percent of total system energy in some applications.

- A blood bank purification process—a laser treatment process is being developed that cleanses donor blood bank supplies of herpes, measles, hepatitis-B, and the virus that causes AIDS.

- New materials for car engine parts—high-temperature carbon fiber ceramic materials are being tested for car engine components. These components are more durable than steel, will increase automobile service life, and reduce maintenance costs.

- Diamond crystal coating technology—a new process has been developed to grow thin layers of diamond crystal on surfaces. This process can be used to make semiconductors; protect eyeglasses, windows, and mirrors; and harden tool surfaces to cut, grind, and manufacture tools and parts.

In addition to spinoffs spawned in these scientific and technical areas, SDI research is also creating commercial and R&D opportunities in superconductivity, communications, lasers, industrial manufacturing processes, electronics, and microwave technology. Specific examples, sorted by program element, are provided below.

Systems Analysis/Battle Management

Advances in computing power and signal processing resulting from the SDI Program will find use in other large programs, such as the NASA Space Station and the National Aerospace Plane.

The manufacturing projects are major users of robotics and automation technologies, as applied to efficient, high-quantity manufacturing. Similar use of this technology in the commercial sector is highly likely.

Surveillance, Acquisition, Targeting, and Kill Assessment

A significant nonmilitary use for laser radar involves atmospheric sensing and identification of upper atmospheric molecules from remote platforms or satellites.

Kinetic Energy Weapons

An interesting potential application for hypervelocity gun technology is to utilize the device for mass transfer from the lunar surface to low earth orbit, e.g., for mining the moon. Several universities have conducted studies to determine the technical and economic effectiveness of this concept.

Directed Energy Weapons

Directed energy projects offer a number of opportunities to transfer very advanced technology to the civilian sector. For example, linear accelerator (linac) technology developed at the Department of Energy's Los Alamos National Laboratory (LANL), New Mexico, in response to SDI neutral particle beam (NPB) requirements, are now being used as a source of innovation for medical, industrial, and scientific research.

The radio frequency quadripole (RFQ) linac, a device through which a beam of positively charged hydrogen or deuterium ions travels and accelerates to increase the energy of the particles, was tested at LANL in 1980. It was then used to further define NPB requirements for SDI directed energy research as the baseline design for the accelerator used in SDI NPB integrated space experiments. The RFQ linac's design has been modified for use in other types of scientific and technical research. Applications for which the linac is now being used include the following:

- Cancer therapy research: A modified RFQ linac design is being integrated into a proton therapy cancer treatment facility now being built by Loma Linda University Hospital in southern California. It is anticipated that three to five more facilities for using this technology will be built in the next few years.

- Airport bomb detectors: The Federal Aviation Administration is evaluating SDI research regarding the use of RFQ linac technology as a neutron source with which the bomb detector bathes luggage with low-energy neutrons. High-nitrogen content explosives that may be in the luggage absorb the neutrons and emit a characteristic gamma radiation which can be detected by the system's scanners.

- Nondestructive inspection: A U.S. Navy small business innovation research contract has been awarded to an SDI contractor to develop equipment using the RFQ linac as part of a nondestructive inspection system designed to inspect rocket motor components. This system could be used to

detect potential component failure and other problems caused by corrosion, internal damage, or structural defects.

The very high-current particle accelerators from free-electron laser (FEL) and NPB devices should provide the high-energy nuclear physics community with an enhanced data collection capability to conduct new research in nuclear structures.

The optics technology utilized in the FEL projects should allow astronomers to correct for atmospheric and instrument aberrations, thus enhancing observational astronomy and high-resolution imaging. This technology is also applicable to laser communications systems for high data transmission.

Survivability, Lethality, and Key Technologies

Potential benefits of laser vulnerability tests include laser welding and laser surface treatments to harden or coat material surfaces.

Space materials research and development will provide lightweight structures and stable, passively damped structures for large civilian projects such as NASA's Space Station.

Materials hardened to kinetic energy threats may provide useful insights into the design of hardened, friction-resistant components for commercial or government use.

Superconducting energy storage and transmission systems are prominent examples of technologies that will have widespread use in commercial applications. The advent of high-temperature superconductors should make magnetic levitation trains viable, and energy storage systems like the Super Magnetic Energy Storage device will keep power plant utilization high by providing energy storage during slack demand periods for use during peak load periods. Other high-temperature superconducting component applications include radar filters, infrared detectors, and low-loss electrical equipment/motors.

An ion beam surface-texturing technique being developed for battle-hardened sensor baffles has been applied to tailor the tip surface of pacemaker electrodes. The resulting improved electrode has been shown to increase battery life by three times and reduce the frequency of battery replacement. Animal studies have been successfully completed and the technology application is awaiting Food and Drug Administration approval for human tests.

Improved ion implantation work, also being undertaken to harden sensor baffles, holds the promise of improving life and performance of knee and hip replacement joints and making these replacements potentially available to younger, more physically active users. The improved joints are being readied for animal tests.

Appendix F

SDI Program Funding

Appendix F
SDI Program Funding

SDI Program funding for FY 1989 through FY 1991 is summarized by function in Figure F-1. The estimated funding required to reach the next milestone for each major program is provided in Figure F-2.

Figure F-1 (1 of 3)
SDI Program Funding Functional Summary

Project Number	Title	Apprt'd FY89 (In M$)	FY90 Apprt'd (In M$)	FY91 Reqst'd (In M$)
Initial Systems				
Systems Engineering				
2301	Design and Integration	1.0	0.0*	0.0*
3100	Systems Engineering	47.6	68.9	75.0
3104	Integrated Logistics and Support (ILS)	7.8	6.8	8.1
3105	Producibility and Manufacturing	6.7	9.8	10.3
3107	Civil Engineering	5.5	4.3	4.5
3108	Operational Environment	0.0	0.8	1.2
3201	Architecture Studies	10.0	12.5	15.2
3202	Operations Interface	2.7	6.6	7.1
3203	Threat Development	4.8	11.6	13.5
	Subtotal	**86.1**	**121.2**	**135.0**
Sensors, Command Center, and System Integration Function				
2101	Boost Surveillance and Tracking System (BSTS)	233.1	300.0	402.0
2102	Space-Based Surveillance and Tracking System (SSTS)	93.0	78.0	95.0
2103	Ground-Based Surveillance and Tracking System (GSTS)	10.4	40.0	100.0
2104	Ground-Based Radar (GBR)	71.0	89.0	150.0
2300	CC/SOIF Systems	115.5	87.8	140.2
	Subtotal	**522.9**	**594.8**	**887.2**
Initial Kinetic Energy Weapons				
2205	Brilliant Pebbles	46.0	129.0	329.0
2201	Weapon Systems	116.0	73.0	53.0
2202	Ground-Based Interceptor (GBI)	162.8	127.7	142.0
	Subtotal	**324.8**	**329.7**	**524.0**
System Validation				
3302	National Test Bed	112.9	125.0	140.0
3303	Independent Test and Evaluation Oversight	4.8	4.3	5.5
3304	Test and Evaluation Resources	15.0	46.8	58.0
3306	Advanced Research Center (ARC)	13.4	13.5	13.8
3307	Midcourse Space Experiment	87.6	56.2	40.3
3308	System Simulator Level II	0.0	0.0	20.0
	Subtotal	**233.7**	**245.8**	**277.6**

* Due to program and organizational restructuring, this work has been transferred to another project.

Figure F-1 (2 of 3)
SDI Program Funding Functional Summary

Project Number	Title	Apprt'd FY89 (In M$)	FY90 Apprt'd (In M$)	FY91 Reqst'd (In M$)
Follow-on Systems				
Follow-on Kinetic Energy Concepts				
1203	Hypervelocity Technologies	23.9	20.2	25.1
2203	High Endoatmospheric Defense Interceptor (HEDI)	113.0	66.0	95.0
	Subtotal	**136.9**	**86.2**	**120.1**
Follow-on Directed Energy				
1301	Free Electron Laser (FEL)	202.7	129.8	130.0
1302	Chemical Laser	99.4	116.8	211.0
1303	Neutral Particle Beam (NPB)	107.6	116.4	165.0
	Subtotal	**409.6**	**363.0**	**506.0**
Sensor Technology				
1101	Passive Sensor	70.3	57.1	65.2
1102	Radar	14.3	0.0	10.0
1103	Laser Radar	80.3	59.0	67.5
1104	Signal Processing	80.2	67.0	77.4
1105	Discrimination	179.0	133.9	170.0
1106	Sensor Studies and Experiments	165.5	181.8	240.5
1107	Interactive Discrimination	8.0	0.0*	0.0*
	Subtotal	**597.7**	**498.6**	**630.6**
CC/SOIF Technology				
1403	Communications Engineering (C&C)	0.0	0.7	0.9
1405	Communications Engineering Technology	0.0	6.3	7.8
	Subtotal	**0.0**	**7.0**	**8.7**
Interceptor Technology				
1201	Interceptor Component Technology	92.6	85.5	106.0
1202	Interceptor Integration Technology	67.1	95.1	115.0
1204	Interceptor Studies and Analysis	47.8	12.5	20.4
	Subtotal	**207.5**	**193.1**	**241.4**
Directed Energy Technology				
1304	Nuclear Directed Energy	21.4	13.0	15.0
1305	Acquisition, Tracking, Pointing/Fire Control (ATP/FC)	237.2	273.5	225.0
2204	Directed Energy Weapon (DEW) Systems	22.6	8.0	12.0
4102	Strategic Defense Facility	4.7	10.0	2.3
	Subtotal	**285.9**	**304.5**	**254.3**

* Due to program and organizational restructuring, this work has been transferred to another project.

Figure F-1 (3 of 3)
SDI Program Funding Functional Summary

Project Number	Title	Apprt'd FY89 (In M$)	FY90 Apprt'd (In M$)	FY91 Reqst'd (In M$)
Key Technologies				
1501	Survivability	102.8	107.1	136.0
1502	Lethality and Target Hardening	62.0	38.9	40.0
1503	Power and Power Conditioning	108.9	83.6	90.0
1504	Materials and Structures	30.8	35.6	42.0
	Subtotal	**304.5**	**265.2**	**308.0**
Space Transportation				
1505	Space Transportation	57.4	32.0	27.0
	Subtotal	**57.4**	**32.0**	**27.0**
Innovative Sciences				
1601	Innovative Science and Technology (IST)	113.8	113.4	116.8
	Subtotal	**113.8**	**113.4**	**116.8**
Technology Applications				
4302	Technology Transfer	1.2	2.7	2.4
4305	Medical Technology	16.5	20.2	21.0
	Subtotal	**17.7**	**23.0**	**23.4**
Countermeasures				
3204	Countermeasures	17.2	17.1	22.4
	Subtotal	**17.2**	**17.1**	**22.4**
Theater Defense				
1205	Foreign Technology Support	15.2	5.5	11.8
1206	Theater Interceptors	60.5	84.5	75.2
3205	Theater Missile Defense (TMD) Special Studies	19.8	13.6	15.7
3305	Theater and Test Beds	7.6	26.6	40.9
	Subtotal	**103.1**	**130.2**	**143.6**
Management				
4000-5002	Operational Support Costs	208.6	246.5	234.0
	Subtotal	**208.6**	**246.5**	**234.0**
TOTAL RDT&E		**3,627.4**	**3,571.2**	**4,460.0**
MILCON		**83.3**	**33.5**	**11.4**
DOD TOTAL		**3,710.4**	**3,604.7**	**4,471.4**
DOE SDIO		**240.3**	**214.4**	**191.9**
DOD/DOE		**3,950.7**	**3,819.1**	**4,663.3**

* Due to program and organizational restructuring, this work has been transferred to another project.

Figure F-2
Estimated Funding Required to Meet Next Milestone
(In Millions of FY 1988 Dollars)

Program/Project	**Required After FY 1991**	**Description of Milestone**
Ground-Based Interceptor	792	Complete demonstration/validation
Ground-Based Radar	321	Complete demonstration/validation
Ground-Based Surveillance and Tracking System	736	Complete demonstration/validation
Space-Based Surveillance and Tracking System	1,538	Complete demonstration/validation
Boost Surveillance and Tracking System	0	Demonstration/validation complete, FY 1991
Brilliant Pebbles	860	Complete demonstration/validation
Command Center	1,751	Complete demonstration/validation
High Endoatmospheric Defense Interceptor	76	KITE-3 intercept of cooperative RV
Chemical Laser	433	Prove efficacy for entry-level weapon
Free Electron Laser	423	Prove efficacy for entry-level weapon
Neutral Particle Beam	227	Complete concept evaluation/definition
Acquisition, Tracking, and Pointing	144	Starlab experiment

List of Acronyms

List of Acronyms

ABM	Antiballistic Missile
ADI	Air Defense Initiative
ALS	Advanced Launch System
AMOS	Air Force Maui Optical Station
AOA	Airborne Optical Adjunct
APS	American Physical Society
ASAT	Antisatellite
ASM	Antiship Missile
AST	Airborne Surveillance Testbed
ATBM	Antitactical Ballistic Missile
ATM	Antitactical Missile
ATP	Acquisition, Tracking, and Pointing
ATP/FC	Acquisition, Tracking, Pointing, and Fire Control
AWACS	Airborne Warning and Control System
Be	Beryllium
BEAR	Beam Experiment Aboard Rocket
BM/C^3	Battle Management/Command, Control, and Communications
BMD	Ballistic Missile Defense
BP	Brilliant Pebbles
BSTS	Boost Surveillance and Tracking System
BTI	Balanced Technology Initiative
C^2	Command and Control
C^2I	Command, Control, and Information
C^3	Command, Control, and Communications
CC	Command Center
CCE	Command Center Element
CC/SOIF	Command Center/System Operation and Integration Functions
CD	Concept Definition
CIA	Central Intelligence Agency
CIRRIS	Cryogenic Infrared Radiance Instrumentation for Shuttle
CO_2	Carbon Dioxide
COI	Critical Operational Issues
CONUS	Continental United States
CTE	Common Test Environment
CW	Continuous Wave
CWDD	Continuous Wave Deuterium Demonstrator
DAB	Defense Acquisition Board
DANASAT	Direct Ascent Nuclear Antisatellite
DARPA	Defense Advanced Research Projects Agency
DART	Defense Acquisition Review Team
Dem/Val	Demonstration/Validation
DEW	Directed Energy Weapon(s)
DIA	Defense Intelligence Agency
DOD	Department of Defense
DOE	Department of Energy
DRB	Defense Resources Board
DSP	Defense Support Program
DST	Defense Suppression Threat
EA	Environmental Analyses
EADTB	Extended Air Defense Test Bed
EML	Electromagnetic Launcher
EDX	Exoatmospheric Discrimination Experiment
ERINT	Extended Range Interceptor Technology

ERIS	Exoatmospheric Reentry Vehicle Interceptor Subsystem
EXCEDE	Electron Accelerator Equipment
FEL	Free Electron Laser
FOV	Field of View
FPA	Focal Plane Array
FSD	Full-Scale Development
FTV	Functional Technology Validation
FY	Fiscal Year
GBFEL TIE	Ground-Based Free Electron Laser Technology Integration Experiment
GBI	Ground-Based Interceptor
GBL	Ground-Based Laser
GBR	Ground-Based Radar
GBR-X	Ground-Based Radar - Experimental
GHz	GigaHertz
GSTS	Ground-Based Surveillance and Tracking System
GTA	Ground Test Accelerator
GVSC	Generic VHSIC Spaceborne Computer
HALO	High Altitude Learjet Observatory
HEDI	High Endoatmospheric Defense Interceptor
HF	High Frequency
HgCdTe	Mercury Cadmium Telluride
HTS	High Temperature Superconductivity
HVG	Hypervelocity Gun
HYWAYS	Hybrids With Advanced Yield for Surveillance
IAS	Israeli Architecture Study
IBC	Impurity Band Conductor
IBSS	Infrared Background Signature Survey
ICBM	Intercontinental Ballistic Missile
IG	Inspector General
IMU	Inertial Measurement Unit
INSURE	Integrated Survivability Experiments
IR	Infrared
IRIS	Infrared Imaging System
IRM	Information Resources Management
IRR	Interim Requirements Review
IST	Innovative Science and Technology
ITB	Israeli Test Bed
JCS	Joint Chiefs of Staff
JDAI	Joint SDI Defense Technology Applications Initiative
JOR	Joint Operational Requirements
JSTPS	Joint Strategic Target Planning Staff
J-T	Joule Thomson
KBS	Knowledge-Based System
KDEC	Kinetic Digital Emulation Center
KEW	Kinetic Energy Weapon(s)
KHILS	Kinetic Hardware-in-the-Loop Simulator
KITE	Kinetic Energy Kill Vehicle Integrated Technology Experiment
KKV	Kinetic Kill Vehicle
KV	Kill Vehicle
LACE	Low-Power Atmospheric Compensation Experiment
LAMP	Large Advanced Mirror Program
LANL	Los Alamos National Laboratory
LEAP	Lightweight Exoatmospheric Projectile
LHX	Light Helicopter Experimental
LINAC	Linear Accelerator
LLNL	Lawrence Livermore National Laboratory
LODE	Larger Optics Demonstration Experiment
LOWKATER	Low Weight KEW Active Tracker
LREP	Lightweight Replica Decoys
LSI	Large-Scale Integrated
LWIR	Long-Wavelength Infrared
ManTech	Manufacturing Technology

MCS	Midcourse Sensor(s)
MEO	Medium Earth Orbit
MeV	Million Electron Volts
MFEL	Medical Free Electron Laser
MHD	Magneto-Hydrodynamics
MIRV	Multiple Independently Targetable Reentry Vehicle
MLI	Multilayer Insulation
MMW	Millimeter-Wave
MOA	Memorandum of Agreement
MOD	Ministry of Defense
MODIL	Manufacturing Operations Development and Integration Laboratory
MOPS	Million Operations Per Second
MOU	Memorandum of Understanding
M&S	Materials and Structures
MSX	Midcourse Space Experiment
MWIR	Medium-Wavelength Infrared
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBTS	Neutral Beam Test Stand
NDEW	Nuclear Directed Energy Weapons
NHTF	National Hover Test Facility
NPB	Neutral Particle Beam
NPG	Nuclear Planning Group
NTB	National Test Bed
OAMP	Optical Airborne Measurement Program
OC	Operations Center
OPP	Other Physical Principles
OTH-B	Over-the-Horizon Backscatter
PATHS	Precursor Above-the-Horizon Sensor
PBV	Post-Boost Vehicle
PCC	Pilot Command Center
PE	Program Element
PFC	Prototype Flight Cooler
PM	Program Manager
PMA	Program Management Agreement
P&M	Producibility and Manufacturing
PRB	Planning and Resource Board
PSD	Power System Demonstrator
RAM	Random Access Memory
R&D	Research and Development
RF	Radio Frequency
RFQ	Radio Frequency Quadripole
RME	Relay Mirror Experiment
RSRE	Royal Signal and Radar Establishment
RV	Reentry Vehicle
SA/BM	System Analysis/Battle Management
SAE	Service Acquisition Executive
SALT	Strategic Arms Limitation Talks
SATKA	Surveillance, Acquisition, Tracking, and Kill Assessment
SBI	Space-Based Interceptor
SBIR	Small Business Innovative Research
SBL	Space-Based Laser
SDC	Strategic Defense Command (USA)
SDCC	Space Defense Control Center
SDI	Strategic Defense Initiative
SDIAE	Strategic Defense Initiative Acquisition Executive
SDIO	Strategic Defense Initiative Organization
SDS	Strategic Defense System
SE	Systems Engineering
SE&I	Systems Engineering and Integration
SLBM	Submarine-Launched Ballistic Missile
SLKT	Survivability, Lethality, and Key Technologies
SLOC	Sea Lines of Communications
SLT	Strategic Laser Technology

SMES	Superconducting Magnetic Energy Storage
SOIF	System Operation and Integration Functions
SPADATS	Space Defense Acquisition and Tracking System
SPAS	Shuttle Power Satellite
SPC	Special Program Center
SPEAR	Space Power Experiments Aboard Rockets
SPIRIT	Space Infrared Imaging Telescope
SRAM	Static Random Access Memory
SRMP	Sounding Rocket Measurement Program
SSGM	Strategic Scene Generation Model
SSPM	Solid-State Photomultiplier
SSTS	Space-Based Surveillance and Tracking System
STAR	System Threat Assessment Report
START	Strategic Arms Reduction Talks
SUPER	Survivable Solar Power Subsystem Demonstrator
SVS	SSTS Validation Satellite
SWIR	Short-Wavelength Infrared
TAIS	Technology Applications Information Systems
TBM	Theater Ballistic Missile
TCE	Three Color Experiment
T&E	Test and Evaluation
THAAD	Tactical High Altitude Area Defense
TIE	Technology Integration Experiment
TIR	Terminal Imaging Radar
TMD	Theater Missile Defense
TMDAS	Theater Missile Defense Architecture Studies
TW/AA	Tactical Warning/Attack Assessment
TWG	Threat Working Group
UKAS	United Kingdom Architecture Study
USAF	U.S. Air Force
USASDC	U.S. Army Strategic Defense Command
USCINCSPACE	Commander-in-Chief, U.S. Space Command
USD(A)	Under Secretary of Defense (Acquisition)
USSPACECOM	U.S. Space Command
UV	Ultraviolet
VHSIC	Very High-Speed Integrated Circuit
VIS/UV	Visible/Ultraviolet
VLSIC	Very Large-Scale Integrated Circuit
VUE	Visible/Ultraviolet Experiment
WESTPAC	Western Pacific
XTB	Exoatmospheric Test Bed
XTV	Experimental Test Vehicle

Glossary

Glossary

Acquisition—The process of searching for and detecting a potentially threatening object in space. An acquisition sensor is designed to search a large area of space and to distinguish potential targets from other objects against the backdrop of space.

Algorithms—Rules and procedures for solving a problem.

Antiballistic Missile System—A missile system designed to intercept and destroy a strategic offensive ballistic missile or its reentry vehicles.

Antisatellite Weapon—A weapon designed to destroy satellites in space. The weapon may be launched from the ground or an aircraft or be based in space. The target may be destroyed by nuclear or conventional explosion, collision at high speed, or directed energy beam.

Architecture—Description of all system functional activities to be performed to achieve the desired level of defense, the system elements needed to perform the functions, and the allocation of performance levels among those systems elements.

Ballistic Missile—A guided vehicle propelled into space by rocket engines. Thrust is terminated at a predesignated time after which the missile's reentry vehicles are released and follow free-falling trajectories toward their ground targets under the influence of gravity. Much of a reentry vehicle's trajectory will be above the atmosphere.

Battle Management—A function that relies on management systems to direct target selection and fire control, perform kill assessments, provide command and control, and facilitate communication.

Boost—The first portion of a ballistic missile trajectory during which the missile is being powered by its engines. During this period, which usually lasts 3 to 5 minutes for an ICBM, the missile reaches an altitude of about 200 km whereupon powered flight ends and the missile begins to dispense its reentry vehicles. The other portions of missile flight, including midcourse and reentry, take up the remainder of an ICBM's flight time of 25 to 30 minutes.

Booster—The rocket that propels the payload to accelerate it from the earth's surface into a ballistic trajectory, during which no additional force is applied to the payload.

Brightness—The unit used to measure source intensity. To determine the amount of energy per unit area on target, both source brightness and source-target separation distance must be specified.

Bus—Also referred to as a post-boost vehicle, it is the platform on which the warheads of a single missile are carried and from which warheads are dispensed.

Carrier Vehicle (CV)—A space platform whose principal function is to house the space-based interceptors in a protected environment prior to use.

Chaff—Strips of frequency-cut metal foil, wire, or metallized glass fiber used to reflect electromagnetic energy usually dropped from aircraft or expelled from shells or rockets as a radar countermeasure.

Chemical Laser—A laser in which a chemical action is used to produce pulses of intense light.

Communication—Information or data transmission between two or more ground sites, between satellites, or between a satellite and a ground site.

Decoy—A device constructed to simulate a nuclear-weapon-carrying warhead. The replica is less costly and much less massive; it can be deployed in large numbers to complicate enemy efforts to read defense strategies.

Directed Energy—Energy in the form of atomic particles, pellets, or focused electromagnetic beams that can be sent long distances at, or nearly at, the speed of light.

Directed Energy Device—A device that employs a tightly focused and precisely directed beam of very intense energy, either in the form of light (a laser) or in the form of atomic particles traveling at velocities at or close to the speed of light (particle beams). (See also Laser.)

Discrimination—The process of observing a set of attacking objects and differentiating between decoys or other nonthreatening objects and actual threat objects.

Electromagnetic Gun—A gun in which the projectile is accelerated by electromagnetic forces rather than by an explosion as in a conventional gun.

Endoatmospheric—Within the earth's atmosphere, generally considered to be at altitudes below 100 kilometers.

Engagement Time—The amount of time that a weapon platform takes to negate (destroy or incapacitate) a given target. This includes not only firing at the target, but all other necessary weapon functions involved that are unique to that particular target.

Excimer Laser—Also called "excited dimer" laser, which uses the electrically produced excited states of certain molecules such as rare gas halides (which produce electromagnetic radiation in the visible and near-ultraviolet part of the spectrum).

Exoatmospheric—Outside the earth's atmosphere, generally considered to be at altitudes above 100 kilometers.

Exoatmospheric Reentry Vehicle Interceptor Subsubsystem (ERIS)—The original name that refers to the Lockheed variant of a ground-based interceptor (GBI) that could be used in a strategic defense system.

Fluence—The amount of energy per unit area on target. (It should be specified whether this is incident or absorbed fluence.)

Gamma Ray—Electromagnetic radiation resulting from nuclear transitions.

Ground-Based Interceptor (GBI)—The generic name for a ground-based interceptor, such as ERIS.

Ground Entry Point (GEP)—The point where sensor data and other information are received by a ground station.

Hardening—Measures that may be employed to render military assets less vulnerable.

Hypervelocity Gun (HVG)—A gun that can accelerate projectiles to 5 kilometers per second or more; for example, an electromagnetic or rail gun.

Imaging—The process of identifying an object by obtaining a high quality image or profile of it.

Intercontinental Ballistic Missile (ICBM)—A land-based ballistic missile with a range greater than 3,000 nautical miles.

Intermediate-Range Ballistic Missile (IRBM)—A land-based ballistic missile with a range of 500 to 3,000 nautical miles.

Kinetic Energy—The energy from the motion of an object.

Kinetic Energy Interceptor—An interceptor that uses a nonexplosive projectile moving at a very high speed to destroy a target on impact. The projectile may include homing sensors and on-board rockets to improve its accuracy, or it may follow a preset trajectory (as with a shell launched from a gun).

Laser (Light Amplification by the Stimulated Emission of Radiation)—A device for producing an intense beam of coherent light. The beam of light is amplified when photons (quanta of light) strike excited atoms or molecules. These atoms or molecules are thereby stimulated to emit new photons (in a cascade of chain reaction) which have the same wavelength and are moving in phase and in the same direction as the original photon. A laser may destroy a target by heating, melting, or vaporizing its surface.

Layered Defense—A defense that consists of several layers that operate at different portions of the trajectory of a ballistic missile. Thus, there could be a first layer (e.g., boost) of defense with remaining targets passed on to succeeding layers (e.g., midcourse, terminal).

Leakage—The percentage of intact and operational warheads that get through a defensive system.

Lethality—State of effectiveness of an amount of energy or other beam characteristic required to eliminate the military usefulness of enemy targets by causing serious degradation or destruction of a target system.

Midcourse—That portion of the trajectory of a ballistic missile between boost/post-boost and reentry. During this portion of the missile trajectory, the target is no longer a single object but a swarm of RVs, decoys, and debris falling freely along preset trajectories in space.

Multiple Independently Targetable Reentry Vehicle (MIRV)—A package of two or more reentry vehicles which can be carried by a single ballistic missile and guided to separate targets. MIRVed missiles employ a warhead-dispensing mechanism called a post-boost vehicle which targets and releases the warheads.

Neutral Particle Beam (NPB)—An energetic beam of neutral atoms (no net electric charge). A particle accelerator accelerates the particles to nearly the speed of light.

Non-nuclear Kill—Destruction that does not involve a nuclear detonation.

Particle Beam—A stream of atoms or subatomic particles (electrons, protons, or neutrons) accelerated to nearly the speed of light.

Particle Beam Device—A device that relies on the technology of particle accelerators (atom smashers) to emit beams of charged or neutral particles which travel near the speed of light. Such a beam could theoretically destroy a target by several means, e.g., electronics upset, electronics damage, softening/melting of materials, sensor damage, and initiation of high explosives.

Passive Sensor—A sensor that detects only radiation naturally emitted (infrared radiation) or reflected (sunlight) from a target.

Penetration Aid—A device, or group of devices, that accompanies a reentry vehicle during its flight to spoof or misdirect defenses and thereby allow the RV to reach its target.

Post-Boost—The portion of a missile trajectory following boost and preceding midcourse.

Post-Boost Vehicle (PBV)—The portion of a missile payload that carries the multiple warheads and has maneuvering capability to place each warhead on its final trajectory to a target. (Also referred to as a "bus.")

Rail Gun—A device using electromagnetic launching to fire hypervelocity projectiles. Such projectile launchers will have very high muzzle velocities, thereby reducing the lead angle required to shoot down fast objects.

Reentry Vehicle (RV)—The part of a ballistic missile that carries the nuclear warhead to its target. The RV is designed to reenter the earth's atmosphere in the terminal portion of its trajectory and proceed to its target.

Responsive Threat—A threat that has been upgraded in quality or quantity or with added protective countermeasures in response to a projected capability of defeating (all or part of) the threat.

Sensor—A device that detects and/or measures certain types of physically observable phenomena.

Signature—The characteristic pattern of the target observed by detection and identification equipment.

Surveillance—An observation procedure that includes tactical observations, strategic warning, and meteorological assessments, by optical, infrared, radar, and radiometric sensors on spaceborne and terrestrial platforms.

Survivability—The capability of a system to avoid or withstand hostile environment without suffering irreversible impairment of its ability to accomplish its designated mission.

Terminal—The final portion of a ballistic missile trajectory during which warheads and penetration aids reenter the atmosphere. This follows midcourse and continues until impact or detonation.

Tracking and Pointing—Once a target is detected, it must be followed or "tracked." When the target is successfully tracked, an interceptor, laser, or neutral particle beam is "pointed" at the target. Tracking and pointing are frequently integrated operations.

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